JOURNAL

of the

AMERICAN WELDING SOCIETY

Copyright 1930, by the American Welding Society,
33 West Thirty-ninth Street, New York

Subscription $10.00 per year to United States. $11.00 to Canada. Libraries $5.00.
Back numbers, per copy: Members, $0.50; Non members, $1.00.

The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Volume 9 MARCH, 1930 No. 3

TABLE OF CONTENTS

Society and Related Activities

Page

Technical Program Annual Meeting ... 3
Samuel Wylie Miller Medal ... 5
All-Welded Factory Building ... 5
Program of the 5th Annual Welding Symposium ... 5
New Welding Encyclopaedia ... 5
New Headquarters ... 6
Welding in Europe ... 6
Welded Ship ... 6
Annual Dinner ... 8
Code for Pressure Piping ... 8
New Sections of the Society ... 8
Section Activities ... 9
Employment Service Bulletin ... 10

Technical Papers, Items and Reports

Cathode Energy of the Iron Arc, by G. E. Doan ... 11
Electrically Welded Structures Under Dynamic Stress, by Morris Stone and J. G. Ritter ... 15
Welding Stainless Steel and Monel Metal, by M. E. Olsen ... 25
Resistance Seam Welding in 1929, by W. H. Gibb ... 32
Large Scale Ornamental Work, by DeW. Endicott ... 33
Four Years' Experience with Structural Welding, by A. L. Wilson ... 38
Arc Welded Steel Deck Roofs, by A. F. Davis ... 54
Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers 57
Arc Welding of Structural Steel, by J. J. Wallace ... 61
Application of Arc Welding to Machine Design and Building Construction, by A. M. Candy ... 66
Material Transfer in Welding, by A. W. Slocum ... 73
Current Welding Literature ... 74

SECTION OFFICERS AND HEADQUARTERS

PHILADELPHIA

Engineers' Club, 1317 Spruce St., Philadelphia, Pa.

Chairman—J. J. Dunne, Paschall Oxygen Co., 23rd St. and Island Ave., Philadelphia
Secretary—H. E. Hopkins, 709 W. Huntington St., Philadelphia, Pa.

CHICAGO

608 So. Dearborn St., Chicago

Chairman—H. E. Gannett, Chicago, Burlington & Quincy R. R.
Secretary—M. S. Hendricks, The Acetylene Journal, Chicago.

PITTSBURGH

311 Ross St.

Chairman—W. W. Reddie, Westinghouse Elec. & Mfg. Co.
Secretary—G. H. Danforth, Jones & Laughlin Steel Corp.

NEW YORK

33 West Thirty-ninth St., New York

Chairman—A. F. Keogh, Sound Welding Company.
Secretary—C. Kandel, Craftsweld Equipment Corp.

NORTHERN NEW YORK

General Electric Co., Schenectady, N. Y.

Chairman—H. W. Tobey, General Electric Co., Pittsfield, Mass.
Secretary—F. M. Jefts, General Electric Co.

CLEVELAND

Engineer's Room, Carnegie Hall, Cleveland

Chairman—E. W. P. Smith, 1810 Union Trust Building.
Secretary—O. J. Bornemann, Euclid Crane & Hoist Co., Euclid, Ohio.

SAN FRANCISCO

Park Ave. & Halleck, Emeryville, Cal.

Chairman—M. Rhine, General Electric Co.
Secretary—H. W. Saunders, Air Reduction Sales Co.

LOS ANGELES

526 American Bank Building

Chairman—W. A. F. Millinger, Shell Oil Co.
Secretary—G. H. Montfort, Shell Oil Co.

BOSTON

Affiliated Technical Societies of Boston, 715 Tremont Temple, Boston

Chairman—C. W. Babcock, 10 High St., Boston.
Secretary—H. N. Ewerts, 142 Berkeley St., Boston.

WESTERN NEW YORK

500 Morgan Bldg., Buffalo, N. Y.

Chairman—J. N. Wilson, Donner Steel Co., Buffalo, N. Y.
Secretary—G. W. Swan, J. A. Roebling's Sons Company.

DETROIT

Detroit Edison Company, Detroit

Chairman—H. A. Woofter, Swift Electric Welder Company, Boulevard Temple Bldg
Secretary—M. P. Bailey, Detroit Edison Co., 2000 Second Ave.

PORTLAND

P. O. Box 1899, Station F, Portland, Oregon

Chairman—George C. Dierking, Production Manager, Steel Tank & Pipe Co. of Oregon
Secretary—C. W. Hopp, P. O. Box 1899, Station F, Portland, Ore.

CANADIAN

933 Bay St., Toronto

Chairman—Fred H. Williams, Canadian National Railways.
Secretary—Campbell Bradshaw, Executive Editor, Engineering Times, 933 Bay St. Toronto.

AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 9 March, 1930 Number 3

TENTATIVE PROGRAM

ANNUAL MEETING

AMERICAN WELDING SOCIETY

33 West 39th Street

April 23, 24 and 25, 1930

All Sessions Start Promptly as Scheduled

IMPORTANT NOTICE

Members and their guests are requested to register

WEDNESDAY, APRIL 23, 1930

Morning

10:30 a. m. to 10:30, Room 2, 5th Floor, Business Meeting, F. T. Llewellyn, President, Presiding.

Report of President, Report of Tellers' Committee, Election of Officers.

10:30 a. m. to 12 noon, Room 2, 5th Floor, Technical Session.

"Distribution of Stresses in Fillet Welds," by L. C. Bibber, Bureau of Construction and Repair, Navy Department.

"Investigation of Beams Welded to Columns," by Cyril D. Jensen, Lehigh University.

Afternoon

Inspection Trip. (Tentative) 1:30 p.m.

Members and their guests will assemble in front of the Engineering Societies Building where transportation will be provided for an inspection trip.

Evening

Board of Directors' Meeting, 7:30 p. m.

Meeting of Board of Directors of American Welding Society. Appointment of committee chairmen and other officers. Committee reports. Plans for the coming year.

THURSDAY, APRIL 24, 1930

Morning

Technical Session

10:00 a. m. to 12 noon, Room 2, 5th Floor.

An Architectural Session is being arranged covering welding from the viewpoint of the architect and builder. Three important papers will be presented.

Luncheon

12.30 p. m.

A luncheon for members of the Society has been arranged at the Engineers' Club. Tickets should be reserved in advance. Price $2.00. Reservations limited.

Afternoon

Technical Session

2:00 p. m. to 5, Room 2, 5th Floor.

"Constructing Panel Heating by Welding at British Embassy," by a representative from Wolff & Munier, Inc.

"Battledeck Welded Floor Construction," by Lee H. Miller, American Institute of Steel Construction.

"Stiffness of Welded Beam Connections," by C. H. Jennings, Westinghouse Elec. & Mfg. Co.

Evening

Annual Dinner

6:30 p. m., Annual Dinner.

The dinner, as last year, will be arranged as a stag affair. Unusual efforts are being made by the Dinner Committee to provide a good dinner, prizes and special entertainment. There will be no speakers. Tickets should be secured from the Secretary at once. Price $6.00 per person.

FRIDAY, APRIL 25, 1930

Afternoon

Technical Session

10:00 a. m. to 12 noon, Room 2, 5th Floor.

"An All Welded Barge," by E. H. Ewertz, Consulting Engineer.

"The Needs of the Metropolitan District for Instruction in Welding," by R. F. McKay, International Oxygen Company.

"Welding of Tube Turns," by Nate Lord, Tube-Turns, Inc.

Afternoon

1:45 p. m. to 3:00 p. m.

Meeting of Structural Steel Welding Committee.

3.00 p. m. to 5.

Annual meeting of American Bureau of Welding. Report of progress made by various research committees of the Bureau. Plans for future investigational activities. Election of Officers. Appointment of Executive Committee.

The Samuel Wylie Miller Medal

By action of the Board of Directors of the American Welding Society at its meeting on April 24, 1929, the Samuel Wylie Miller Medal, donated in 1927 by Mr. Miller for the period of his life time, has been established in perpetuity by the Society as a memorial to the donor.

The funds for the support of the medal will be supplied by the Society and will be in the custody of the Treasurer. The award will be made by a Board of Trustees, consisting of three members appointed by the President, one each year for a term of three years (after the first two appointments for one and two years, respectively, have been served).

The Board of Trustees will make the award under the following rules and regulations:

1. Samuel Wylie Miller Medal shall be awarded annually for any meritorious achievement which, in the judgment of the Miller Medal Board of Trustees, has contributed conspicuously to the advancement of the art of fusion welding and cutting.
2. Individuals only, but of any country and of any age, shall be eligible for the award.
3. The award for any calendar year shall be announced and the medal, together with a suitable certificate, presented at an annual meeting following the year for which the award is made.

In accordance with the resolutions of the Board of Directors, the President has appointed the following Board of Trustees for the award of the Miller Memorial Medal:

F. J. King, Linde Air Products Company, chairman. (Term 3 years, April, 1932).

C. A. McCune, American Chain Company. (Term 2 years, April, 1931).

F. M. Farmer, Electrical Testing Labs. (Term 1 year, April, 1930).

Another All-Welded Factory Building

It has been announced that another all-welded factory building will be constructed by Black, Sivalls & Bryson, Inc., of Bartlesville. Okla.

The main building will be 140 feet wide and 260 feet long. It is a Half Monitor type construction, and the height of the main section is 45 feet to the top of the roof. The side walls will be galvanized metal with very large window areas. The entire floor will be a six-inch concrete slab. Only three rows of columns will support the structure and crane-way. The entire area will be served by overhead traveling cranes. One of the cranes will be 60 feet wide and of 5-ton capacity.

Program of the Fifth Annual Welding Symposium

At Lehigh University. Friday, April 11, 1930, from 9:30 A. M. to 9:30 P. M.

9:30 A. M.—Demonstrations and Lectures on Methods for Testing the Soundness of Welds. For example, X-Ray Penetrative Methods, by H. H. Lester, of Watertown Arsenal. Sperry Electrical Testing Apparatus, by representative of Sperry Development Company. Stethoscope Method, by a representative of the Linde Air Products Company.

11:00 A. M.—Demonstration of Welding by Projection of the Crater and Rod and Flame on a Screen in Magnified Form, by Professor Frederick Creedy, of Lehigh University.

2–5 P. M.—Demonstrations of welding and testing of welds as follows:

Butt, spot and thermit welding.

Automatic electric arc, hand electric arc and atomic hydrogen welding.

Gas welding of airplane materials, including duralumin, chrome-molybdenum steel, mild steel tubing, aluminum sheet, Stelliting of airplane tail skids, etc. Also cutting with the oxygen torch.

Testing of welded specimens by longitudinal tension, bending, etc. This includes the specimens, each of which has been inspected for soundness by all of the three methods mentioned previously.

8:00 P. M.—Packard Laboratory Auditorium: Resistance Welding, by M. L. Eckmann, recently welding supervisor of the Ford Motor Company, followed by discussion. Also presentation of the reults of tests of welds completed during the afternoon in the Fritz Engineering Laboratory.

New Welding Encyclopedia

We are advised that the Seventh Edition of the Welding Encyclopedia is now ready. The new encyclopedia

includes the definitions and symbols recommended by the Nomenclature Committee of the American Welding Society and the Building Code of the Society. The subject matter has been extensively revised and enlarged to bring it up to date.

A special arrangement has been made whereby members can place orders for copies at $3.00 through the society, thus effecting a considerable saving.

New Headquarters

The increased growth of membership of the American Welding Society has necessitated the securing of larger headquarters. Through the courtesy of Engineering Foundation, Inc., somewhat larger headquarters were secured in the Engineering Societies Building on the same floor.

Welding in Europe

In an issue of a German magazine published several months ago there appears a report of the research work that is being done in seven colleges. The report is as follows:

At Aachen, research under Professor Wallichs—Influence of "Forward" and "Backward" welding on gas consumption and the quality of the welds.

Professor Eylander is conducting a research on welding pure iron and also on the influence of carbon on the qualities of welds.

At Berlin, Professor Hilpert and his associates are conducting the following researches:

Transfer of material through the arc.
Fluxed electrodes for AC arc welding.
Influence of the welding arc on a base metal.
Oxy-acetylene cutting.
Mechanical and statistical research on the welds used in the railroad construction.
Mechanical and statistical investigation of the strength of welds on rails.
Butt welding of steel of very large cross-sections.
Psychotechnical investigation of welders.
Resistance and gas welding.

At Braunschweig, Professor Schmitz is conducting investigations on welding high alloy steels:

Resistance welding.
Various fluxes used in welding.
Influence of water in the gases of oxy-acetylene torches.
Magnetic analysis of welds.
Limits of weldability with benzol.
Economy of various processes.

At Breslau, Dr. Diepschlag is investigating the welding seams in magnetic fields.

At Danzig, Professor Kayser is investigating the following:

Modulus of electricity.
Elongation of welds produced by autogenous welding, electric arc process and autogenous-electric arc process.
Weldability of various kinds of steels.
Welding on street railways and railroads.
Welding of the bed plate to the slippers in railroad construction.

At Karlsruhe an investigation is being conducted on the electric resistance of the welded street railway track.

Welded Ship

(From News Release)

A welded ship of steel has been constructed and launched successfully in Charleston, S. C. This ship has been named the "Carolinian."

The ship was designed by Richard F. Smith, formerly of the Newport News Shipbuilding & Dry Dock Company.

The vessel is 2500 barrel capacity oil tanker, 120 ft. long, 23 ft. wide and with a 10 ft. draft. The boat was constructed for the Texas Oil Company. It is claimed that a saving of 20 per cent in weight and 25 per cent in construction cost is effected as compared with riveted ships.

This saving is effected by the absence of rivets, bolts and angles. The welded ship has a greater cargo capacity than a riveted ship of the same dimensions and greater speed because of its less resistance when moving through the water. Nine workmen were used on the construction, and the equipment consisted of one cutting torch and one arc welding outfit. 8000 lb. of wire were required as compared with 28,000 lb. of rivets. Four welders were employed.

A little device was perfected to show the amount of current being used and the voltage across the arc.

In the design it was claimed that no distortion or buckling of any part of the structure took place.

The framing is longitudinal, consisting of flat bars 4 in. by 7/16 in., spaced 2 ft. apart. Each longitudinal and each frame is complete from end to end. The longitudinal frames are notched about ¾ of an inch, which fit into similar notches 3½ in. deep

in the transverse web plates and bulkheads and are securely welded together forming a lock. All longitudinal strength members, such as the keel, shell and deck plating and stringers are dovetailed together at the ends and welded.

The plating is fitted in accordance with the lock system, each plate fitting into the next with a dovetail joint approximately one-third the width of the plate in depth. The longitudinal plate seams are fitted coincident to the longitudinal framing and a three-part joint deep welded into the longitudinal and plate.

In fitting the plates in position on the longitudinals, a unique method is employed. To each plate is welded a series of clips, another feature of the tanker's construction. These clips are of the same material as the longitudinal with a hole at the top. By means of a simple hook lever the plate is held against the longitudinal and tack welded in place ready for the welder. The clips are then hammered down against the longitudinal and welded to it, forming additional supports 2 ft. apart the entire length of the framing.

The horizontal transverse bulkhead stiffeners are reeved through slots in the centerline bulkhead, allowing them also to be continued from starboard to port in one piece. Where transverse bulkheads and longitudinals cross, both are split to half the depth of each plate, locked and welded on both sides of the split portion to the integral part of the plates. Every seam throughout the ship has three welds, two inside and one outside.

The deck is supported by ten longitudinal beams with the usual number of frames and bulkheads and, except for the markings left by the welding, the deck, as well as the outer skin of the ship, is smooth. Extra heavy black iron pipe, 2½ in., slit the length of the pipe with a cutting torch, is slipped over the bulwark plating to which it is welded, forming a unique as well as a very substantial bulwark rail. The deck house and living space on the welded boat are aft.

The gain in strength of the welded ship over that of a riveted one is considered of importance. Where general practice in shipbuilding depends upon plating for its longitudinal strength, the welded ship with longitudinal framing has, it is estimated by the designer, 60 per cent added strength in longitudinals. Strength tests of joints and welds showed a close approximation to 100 per cent efficiency.

Annual Dinner

Those who have attended the annual stag dinner of the American Welding Society during the part two years will look forward with pleasure to again attending the dinner this year.

The price for the dinner tickets will be, as usual, $6.00 per person. Members and their guests are requested to make reservations as soon as possible. Tickets may be secured by writing to the Secretary of the Society.

The entertainment which has been provided will be equal to, and, in fact, will surpass that of last year. An unusual number of prizes have been secured by the Dinner Committee which will be given to those having lucky numbers.

Code for Pressure Piping

A committee of the Society under the chairmanship of D. H. Deyoe has been actively at work for the past year or so in the formulation of a code for welded pressure piping. This work is being done in conjunction with the American Society of Mechanical Engineers and the American Standards Association. The code covers all kinds of piping design for pressure work. It is planned to later on make this code as part of the series of codes and specifications issued by the American Welding Society covering welding on important construction work.

New Sections of the Society

Two new Sections of the American Welding Society are in the process of formation, namely, in Tulsa, Okla., and Denver, Col.

Considerable progress has been made in each locality and temporary officers have been selected and preliminary meetings held. Efforts are being concentrated for the present to comply with requirements of the Society to secure 25 new members.

In both localities the enthusiasm is such that there is no doubt that in the course of the next few months a sufficient number of members will be obtained.

Members of the Society are requested to render such assistance as they can in securing new members in these districts. The representatives of the Society in these localities are: Denver, Paul Ross; Tulsa, J. C. Haymaker.

Annual Meeting

There is given at the beginning of this JOURNAL a tentative program for the Annual Meeting. It is planned to publish most of these papers in advance of the meeting in order to assure discussion. Every member of the Society is earnestly requested to make every effort to attend and to read papers in advance and be prepared to discuss them.

Section Activities

Chicago

A descriptive lecture on the Carb-O-Flux Arc Welding Process was given by R. W. Holt, research engineer, Fusion Welding Corporation, at the meeting of the Chicago Section on Feb. 6, at the Greer School. Mr. Holt showed samples of sheet metal welded by this process which created considerable interest. He also gave a demonstration, following the lecture, of gas welding an aluminum casting.

New York

The regular monthly meeting of this Section was held on March 11th. The subject of this meeting was "Resistance Welding." R. T. Gillette, Welding Engineer of the General Electric Company, discussed the advantages of projection welding over the old conventional spot welding; the merits of flash as compared to the old butt-welding; including the welding of non-ferrous as well as dis-similar metals. Flash welding of aluminum was also described ts well as unique projection methods and shortcuts employing resistance welding. The paper was accompanied by lantern slides. A number of those present took part in the discussion.

Detroit

A joint meeting with the Industrial Electrical Engineering Society was held on Feb. 26. W. H. Zorn, general foreman of welding at The Detroit Edison Company, gave an illustrated lecture on "Welding in the Power Plant." The saving in erection costs and quality of work were indicated in the many lines of erection attempted in the varied phases of construction work handled by a public utility company. Both arc and gas welding are used extensively. Mr. Zorn also stated that experiments were being made with welding of stainless steel for high pressure boiler work. The well-planned lecture was received with much interest and many questions were asked the speaker.

Los Angeles

A meeting of the Los Angeles Section was held on Feb. 28. The chairman, W. A. F. Millinger, advised that the executive committee had accepted the invitation of the First Annual Oil Equipment & Engineering Exposition to furnish a program on Tuesday afternoon, March 18, in the Assembly Room of the Shrine Auditorium. Mr. Miller, Mr. Wagner, Mr. Welsh, Mr. McKutchen, of the Department of Buildings and Safety of the City of Los Angeles, were introduced.

C. C. Watson, of the Contract Service Department of the General Electric Company, of Schenectady, N. Y., gave a very interesting paper on "Inspection of Welds and Selection of Welders." Samples of test specimens were shown and a lengthy discussion was had regarding the bending of butt welded plates for testing welds.

Samples of the new battleship deck construction for building floors were shown and a short explanation of the idea was made by G. J. Carrol. These are built up plates with "I" beam supports. As they are in the experimental stage, it was advised that a more complete description would be made at a later date.

Northern New York

The March meeting of this Section was held on the 6th. W. M. Dunlap, of the Aluminum Co. of America, spoke on "Welding of Aluminum and Its Alloys." His talk covered gas

welding and also spot and line welding of aluminum and its alloys.

Portland

The Portland Section held two very successful meetings, one in January and the other in February. The January meeting was addressed by E. Avery Jordan, of the Smith Welding Equipment Company, who spoke on "Bronze Welding as Pertaining to the Plumbing and Heating Trade." The address was accompanied by two reels of films showing in detail the installation of pipe in a large building. These films illustrated the manner in which the piping was installed and the replacement of screwed connections through the use of pipe turns and the welding of all joints. Mr. Jordan's talk and the pictures brought out clearly the advantages of this type of installation as compared to pipe installed with screwed connections. Among these advantages are the elimination of leaks, the reduction in cost and the saving in weight of material. Considerable interest was shown by all present in the discussion which followed.

The meeting in February was held on the 27th. D. C. Grundy, of the Linde Air Products Company, gave an introductory talk on the fabrication and erection of the Union Carbide Research Laboratory Building, the first structure to be erected by the use of oxy-acetylene welding. Two reels of film showed very clearly the steps in the fabrication of the building. The pictures and diagrams showed in detail the design of the joints and the manner in which the welding was done. These films were followed by two reels showing the acetylene welding of 12-in. and 20-in. high pressure gas lines in California. The meeting was followed by an open discussion in which the large number present showed quite plainly their interest in the subject covered by the films and Mr. Grundy's talk.

San Francisco

Another elaborate program was arranged by the program committee for Friday, March 7. Dinner was served at 6:30 p. m., and the business meeting followed at 7:45 p. m. C. E. Rhein of the Linde Air Products Company, spoke on "Oxy-Acetylene Welding and Cutting of Structural Steel." Two reels of moving pictures showing the construction of the research building at Niagara Falls, which was gas welded, were also shown.

W. H. Ost, engineer of the Air Reduction Sales Company, an authority on pipe line welding, spoke informally on some of the pipe lines now being welded in different parts of the country which he recently visited.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

SERVICES AVAILABLE

A-89. Engineer desires position. Age 29, married. Graduated from Oregon State College in M.E. Sales, B. F. Sturtevant Co., San Francisco, Westinghouse Elec. & Mfg. Co. Sales course, Arcos, Inc. Sent to Europe three months studying welding in Belgium, France, Switzerland and England; 18 months engineer demonstration, and sales covering all states east of Missis-

sippi River. Would like welding engineer work. Any location either in United States or South America.

A-91. German emigrant desires to secure position as welder. Have had training as engineer and have had experience in arc welding in replacement of castings. Have letters of introduction and recommendations from Germany.

A-92. Electric arc welder desires position. Can operate an automatic welding machine. Graduate of G. E. Welding School.

A-93. A graduate student of structural engineering who will receive his M.S. degree in June desires a position with an engineering firm that is doing or expects to do considerable welded structural design. Will also consider research work. B.S. in C.E., 1929; Lincoln Electric Company's School for Welders; shop welding experience on a medium sized mill building; research work and Masters Degree thesis on impact resistance of arc welds. Available June 15.

POSITIONS VACANT

V-48. Welding Supervisor wanted. Must be a practical welder and able to train welders. Must be able to weld and do research work on alloy welding such as Chrome Nickel, Monel Metal, Everdur, Copper, etc. Must be familiar with coatings for electrodes and capable of developing same. Must be able to work out a welding procedure and develop the technique for same on any type of welding. Must be able to inspect and check welded work in process.

V-49. Sales engineer desired. Thoroughly familiar with arc welding industry. Need a man to cover New York territory. High grade man desired to establish agencies for the sale of arc welders and to work on the sales of large users of Welders, and to assist branch offices in promotion of Welder sales generally.

BOUND VOLUME 1929

The Bound Volumes of the 1929 Journals are now ready. The twelve issues have been bound together in attractive imitation black leather cover, together with a Subject and Authors' Index. This represents one of the best sources of current welding information. Price to members is $5.00; to non-members $10.00. A few Bound Volumes for the years 1925 to date are also available at the same price.

Cathode Energy of the Iron Arc*

GILBERT E. DOAN

THE electric welding arc has been studied in former instances to determine the chemical changes occurring in the electrode and in the base metal. The tensile strength, hardness, fatigue properties and especially the ductility of weld metal have been examined and discussed by many investigators. Likewise, the internal stresses in welds and the effects of pre-heating and post-heating have been discussed in scientific papers heretofore. The present paper is devoted to the energy changes of the arc rather than to the material changes, and stress changes occurring in welding. It is a preliminary attempt to study quantitatively the energy supplied to the cathode tip of the arc during continuous welding, as such welding is done in good industrial practice. The constants used are, in many cases, not yet accurately known and the results are, therefore, not exact. But the results are useful in enabling the investigator to form a picture of the arc processes and of the relative importance of each feature of the arc.

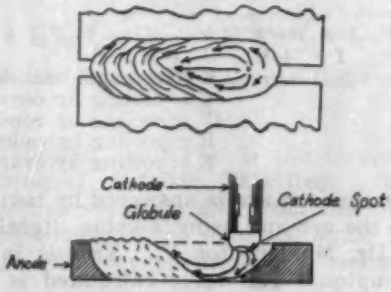


FIG. 1—WELDING ARC

The central idea of this study is to cast up a balance sheet showing the heat used up at the cathode tip of the arc, on one side of the ledger, and the sources of supply of this heat on the other side of the ledger. Since the quantitative nature of this study required a complete theory of the arc, a search of the literature was made for such a theory.

The work of K. T. Compton[1] involving thermionic emission offered the best working basis and was adopted for this reason. The present study was begun early in the year 1927. The work of Stolt[2] and also that of Slepian[3] seems to show that arcs may be obtained also from cold cathodes,

*Abridgment of a paper presented before the A.I.E.E. Winter Convention, Jan. 30, 1930. Contribution to the Fundamental Research Committee, American Bureau of Welding, and Welding Committee, A.I.E.E.

[1] K. T. Compton, *A.I.E.E. Trans.*, Vol. XLVI, 1927.

[2] H. Stolt, Annalen der Physik, Vol. 74, 1924, pp. 80-104; H. Stolt, Zeit. f. Physik, Vol. 262, 1924, pp. 95-101.

where there is no thermionic emission, but in the welding arc this is certainly not the case. Since the arc, once struck, rapidly comes to thermal equilibrium with its environment, the heat income and output must be equal at every point, and at the cathode may be tabulated as follows:

ENERGY BALANCE AT THE CATHODE

Heat *received* at the cathode (calories per second) with 150 amperes:

(1) By ionic bombardment, etc.	121.0
(2) By ohmic resistance in the molten globule (1.96) and adjacent electrode (1.24)	3.20
(3) By radiation from the anode	9.65
(4) By oxidation of iron vapor and mist	9.70
	143.55

Heat *disbursed* at the cathode (calories per second, with 150 amperes flowing):

(5) By melting of electrode (including sensible heats)	161
(6) By evaporation of atoms	12.6
(7) By evaporation of electrons	95.5
(8) By dissociation of iron vapor and air	....
(9) By radiation to anode (9.65) and to surrounding air (8.55)	18.20
(10) By conduction through the electrode shank	0.00
(11) By gaseous convection and conduction	....
	287.3

The equation of Compton, from which items (1) and (7) are calculated is:

$$(1-f)\ (V_c + \phi_+) + F\ [f\ V_c - (1-f)\ V_i] + H = f\ \phi_- + C + C' + R + E$$

f is taken as .625
$V_c = 9.0$ volts
$\phi_+ = 0$
$F = 0$
$\phi_- = 4.25$ volts

H = external heating of the cathode
C = cooling by convection
C' = cooling by conduction
R = cooling by radiation
E = cooling by evaporation

The question of V_c for the iron arc is answered by taking V_i for iron as the conducting gas in the arc and using a value slightly higher than V_i (= 7.83 as given by Dr. Mohler) for V_c. This is in accordance with the experience of Compton. The value calculated is 121 calories per second. It may be that air is the ionizing medium in the iron arc rather than the cathode material, which latter Compton has shown for the carbon and for the mercury arcs. This would lead to a higher result for item (1). Also ϕ_+ may not be zero and f may be much smaller than .625.

Item (2) is small, 3.2 calories per second. It is calculated from the mean dimensions of the globule and from the specific resistivity of iron at 1992 deg. C. To this is added the heat liberated in the electrode just above the globule See Figs. 1 and 2.

Item (3) is calculated by obtaining values for the temperature and area of the anode spot. From these values the radiation can be calculated by the Stephen-Boltzmann law. The temperature is taken as 2450 deg. C., which is the boiling point of iron. The area of the cathode spot is estimated from observations of the arc. The value arrived at is 9.65 calories per second.

[8] J. Slepian, *Journal A.I.E.E.*, February, 1929, p. 93.

Item (4) is interesting. If the 12 per cent of the electrode weight which is lost in welding all burns, it would liberate about 77 calories per second. This would occur not only at the cathode but also at the anode and in the arc stream. If one-quarter of it occurs at the cathode, then one-eighth might be returned to the cathode by reflection. This would be 9.7 calories per second. The effect of this envelope of burning iron upon the arc, which is thus enclosed in it, may be very important, especially in relieving the temperature gradient at the arc.

The sum of these four items is 143.55 calories. The total energy input to the arc is 150 amperes $\times$ 18 volts or 645 calories per second. If 10 per cent of this energy is absorbed in the arc stream[4], it would leave 580 calories for the two electrodes. An equal division of heat between anode and cathode as indicated by Alexander[5] would leave 290 calories at the anode and 290 calories at the cathode. The total 143.55 calculated above is, therefore, too low. The trouble is most probably with the constants taken from Compton and used in item (1). It is to be noted that the arc proper, that is, ionic bombardment, supplies most of the heat and not the attendant circumstances, such as ohmic resistance, radiation and combustion of iron.

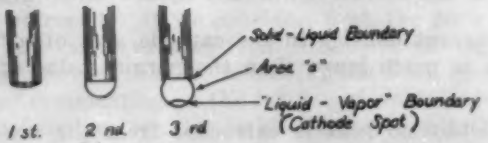


FIG. 2—STAGES OF GLOBULE GROWTH

Under heat disbursement item (5) is the largest 161 calories per second, for the melting of electrode. This item is calculated from the measured rate of melting electrode and from the latent heat of fusion of iron and the sensible heats of the solid and liquid iron so melted. The value shows the high efficiency of the arc in melting electrode—about 50 per cent.

Item (6) 12.6 calories per second, assumes that only half of the "loss to air" in welding is as true vapor carrying the latent heat of vaporization of iron, the remaining loss being as mist and spray.

Item (7) takes iron vapor to be the conducting gas in the arc. Since iron vapor is mon-atomic, the heat of dissociation is zero.

Item (9) shows the total losses from the molten globule, both to the anode and to surrounding air, 18.20 calories per second.

Item (10) is zero. This is true because the electrode is fed into the arc at a greater speed than the heat can flow back from the arc through the electrode.

Item (11) being very small, as shown by Langmuir, is neglected.

[4] Hart, "Welding," p. 37.
[5] P. Alexander, A.I.E.E. Winter Convention, Jan. 30, 1930.

The total for "Disbursement" is 287.3 calories. This agrees well with 290 calories of the 645 total energy input.

The important conclusions which can be drawn from this study are:

1. That the calculation of energy consumption at the cathode corresponds well with the observed rate of melting of electrode, assuming an equal distribution of energy between anode and cathode.

2. That the energy available at the cathode, as here calculated, is insufficient.

3. That most of the heat at the cathode is consumed in melting electrode and in electron evaporation, most of the energy liberated there is due to ion impact and to combustion of iron vapor.

4. There is not enough heat at the cathode to vaporize all the iron deposited.

Incidentally, the following conceptions result:

1. That the amount of radiation from the anode and cathode spots to the neighboring atmosphere is small. Most of the radiation observed comes not from the arc proper, but from the burning envelope of iron about the arc.

2. That the current density in the cathode spot of a "short arc," as used in welding, is much lower than the normal value of 7200 amperes per cm^2.

3. That practically no heat is extracted from the arc by conduction through the cathode wire. The rate of melting outstrips the rate of heat conduction. This applies to "bare" wire electrodes.

Electrically Welded Structure

Under Dynamic Stress

By Morris Stone* and J. G. Ritter†

THE general application of arc welding to all types of construction has extended rapidly during the past few years, but not in the field where dynamic stresses were imposed because of the lack of information on the fatigue resistance characteristics of such welded structures. Even as far back as 1911, Stanton[1] and Abell,[2] after making a series of Wholer tests of welded material, advised against welds for variable stress applications. However, recent investigations such as those described in this paper justify a more general increase in the use of welding under these conditions.

The general nature of the action of weld metal under fatigue is much the same as for virgin metal, except that lower test values are obtained, and less consistency of results. If we consider, first, the pure weld metal, we find endurance limit values varying from ± 9000 lb. per sq. in. to ± 22,000 lb. per sq. in. depending on the care in making the weld, its porosity, size of weld, etc. Dustin,[3] commenting on the fatigue of welds, states the difficulty in obtaining consistent values, due to blow holes, slag inclusion, etc. This aspect of testing has forced the use of large size test pieces for obtaining fatigue values on weld material.[4] The reason for such a necessity can be appreciated when one considers the very nature of a weld, which is porous and non-homogeneous. The effect of a small surface hole will be much more serious on a small specimen than on a large—so that, in general, one should expect higher and more consistent results from large size fatigue specimens.

An active comparison of endurance limits as determined for varying sizes of welds is the object of a present research, and we need not be surprised to find the larger size welds showing lower endurance limits. Such an effect can be explained by the injurious influence of residual stresses in the larger welds, which do not occur in the smaller welds, where they can be relieved by the heat of subsequent welding. Such results would indicate opposite tendencies to those published[5] for tensile strengths, yield points, etc.

From the widely differing values of endurance limit, it is entirely

*Mechanical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
†Welding Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

[1] T. E. Stanton and J. R. Pannell, I. C. E., December, 1911.
[2] W. S. Abell, I. C. E., March, 1919, in an investigation for Lloyd's.
[3] H. Dustin, *Revue Universelle des Mines*, December, 1926.
[4] R. E. Peterson, "Fatigue Tests of Large Specimens," A. S. T. M., June, 1929.
Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930.
[5] G. Lobo, "Strength of Butt Welds," Journal of American Welding Society, April, 1929.

feasible to count on the value of ± 15,000 lb/in². This, it will be realized, must be compared with endurance limits of ± 25,000 lb. per sq. in. for mild carbon steel to as high as ± 60,000 lb. per sq. in. for some alloy steels.

Most structures are rarely subjected to purely variable stress—alternating between equal values of tension and compression—but rather combinations of steady and variable components as illustrated in Fig. 1. The failure of metals under such conditions is still a matter of investigation, and is only now becoming clarified from the point of view of design utility.

One of the most common stress conditions, and probably the most elementary for a material study, is that of simple tension or compression superimposed by a variable stress of smaller magnitude. Experiments, investigating failure under various ratios of steady to variable stress, have been carried out for many years, with certain characteristic relationships becoming evident. If we plot steady stress as abscissas versus

FIG. 1—DIAGRAM ILLUSTRATING COMBINED STEADY AND VARIABLE STRESS

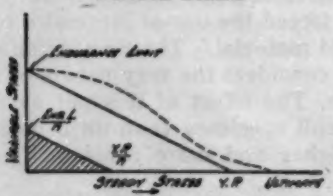


FIG. 2—CURVES SHOWING RELATION BETWEEN VARIABLE AND STEADY STRESSES

variable stress as ordinates,* the experimental curve of failure follows somewhat that shown by the dotted line in Fig. 2. This has been approximated to by Gerber as a parabola, and by Goodman as a straight line connecting endurance limit and ultimate stress, but it is more conservative and easier of application to use the straight line approximation shown connecting endurance limit and yield point.

The relation between allowable variable stress, S_v, and corresponding steady stress, S_s, as defined by the straight line is, where

S_e = Endurance limit

S_y = Yield point

$$\frac{S_v}{S_e} + \frac{S_s}{S_y} = 1$$

* Recent Improvements in Turbine Generators, S. L. Henderson and C. R. Soderberg, A. I. E. E. Quarterly *Trans.*, Vol. 47, April, 1928, p. 549.
"Stress Analysis in Electrical Rotating Machinery," *A. S. M. E. Trans.*, 1928, M. Stone.

Now in the actual applications of arc welded structures, we do not permit ourselves to operate close to failure stresses; therefore the idea of factor of safety must be introduced.

Due to the very many exigencies that may occur in welding, such as poor fusion, impurities, porosity, etc., we, in our design practise, have set a factor of safety of 3 to be used both on the yield point in steady stress applications and on the endurance limit for fatigue. This confines our stresses to the shaded area shown in Fig. 2 and our stress relation now is expressed by

$$\frac{S_v}{S_e}+\frac{S_s}{S_y}=\frac{1}{n}\left(n = \text{factor of safety}\right)$$

For welds, this relation takes on the quantitative aspect of

$$\frac{S_v}{15{,}000}+\frac{S_s}{30{,}000}=\frac{1}{3}$$

The endurance limit and yield point values being taken here are average figures.

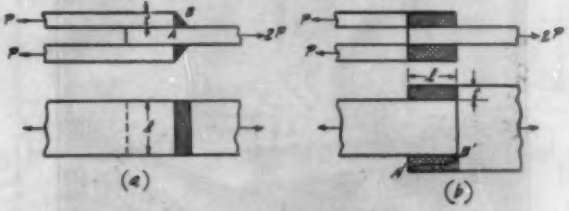


FIG. 2—TWO TYPES OF WELDED JOINTS

To illustrate its use: Suppose we have a pure variable stress, then $S_s = o$, and the allowable S_v is given by

$$S_v = \frac{15{,}000}{3} = 5000 \text{ lb. per sq. in.}$$

On the other hand, suppose we consider a static application, where $S_v = o$, then the allowable stress, S_s is

$$S_s = \frac{30{,}000}{3} = 10{,}000 \text{ lb. per sq.. in.}$$

These are the values adhered to in all designs where welds have to withstand live stress. An intermediate case may be: If $S_s = 5000$ lb per sq. in., what is the allowable variable stress that may be superimposed? Thus

$$\text{Allowable } S_v = \left(\frac{1}{3}-\frac{5000}{30{,}000}\right) 15{,}000 = 2500 \text{ lb. per sq. in.}$$

The design situation becomes more complex where welds are to withstand combined shear and direct stress,[1] or direct stress on planes at right angles to each other. These fields have not as yet been fully investigated experimentally even in the realm of metals themselves, and even less for

[1] F. C. Lea, *Engineering*, Aug. 20, 1926.

welds. This leaves us with the necessity of relying on the well established rules for stress combinations as calculated from the ordinary theory of elasticity, and interpreted as we have discussed above.

At this point, we must inject an idea extraneous to fatigue considerations for pure metals, but one which occurs when heat treated alloy steels are welded together or to ordinary steels. Tests that have recently been made consisted of welding a ring of metal around a heat treated ni-chrome steel (0.56 per cent Cr, 1.17 per cent Ni.) test bar, and then after machining off the bead, subjecting the bar to an alternating stress. The endurance limit dropped from 66,000 lb./in.[2] (for the alloy steel) to 16,200 lb./in.[2] Like reductions were noted in ductility and impact resistance. This important result emphasizes the point that the fatigue strength of welded joints cannot be increased by using high grade parent metal—the effect of welding is to reduce the endurance limit

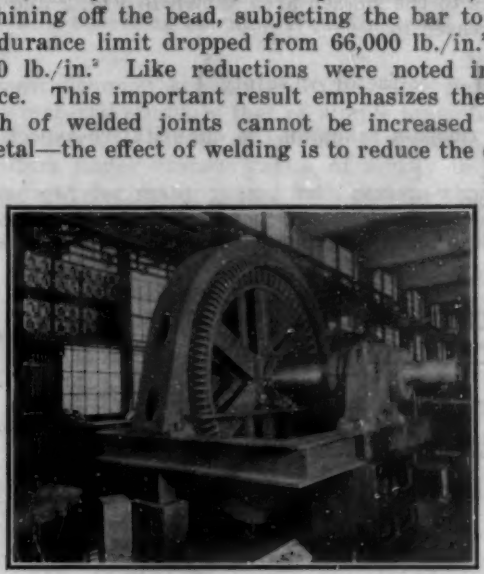


FIG. 4—ARC WELDED A-C GENERATOR

to only average value for mild carbon steel. This fact is important, particularly, where joints are designed to fail in the parent metal and not in the weld. This result, however, is not to be interpreted to apply in the case of static stress, where tensile properties do not appreciably change.

As soon as we begin to extend our ideas to welded joints, much of our knowledge becomes inapplicable. To interpret our information on weld and parent metal for use in welded joints is to assume that the stress distribution is known. This unfortunately is the stumbling block in most cases.

Even in the simplest of welds—fillets, butt, side, or end welds—actual tests must be carried out to determine the upper limit for stress application. And for the great majority of joints, which are made up of combinations of the above, there exists little chance of being able to predict stress distribution.

To examine the simplest of joints, let us compare the two types of joints shown in Fig. 3, the first, a joint of front welds and the second,

a joint of longitudinal or side welds, as to their suitability to withstand dynamic stress.

From tests that have been made in the past, notably by Dustin,[8] the strength of joint (a) is best predicted by considering the section $A\ B$ to be subjected to pure tension and we must associate the stress given by $f = \frac{\sqrt{2}P}{tl}$ with failure.

Failure usually takes place at this critical section. For type (b) welds, the breaking stress can be written as $f = (\alpha \sqrt{2}P)/(tl)$ where α has the value of approximately 2/3. This factor has this low value due to the stress concentration at the ends of the weld, causing the break to progress from A' and B' inward.[9] Despite the lower allowable stress for

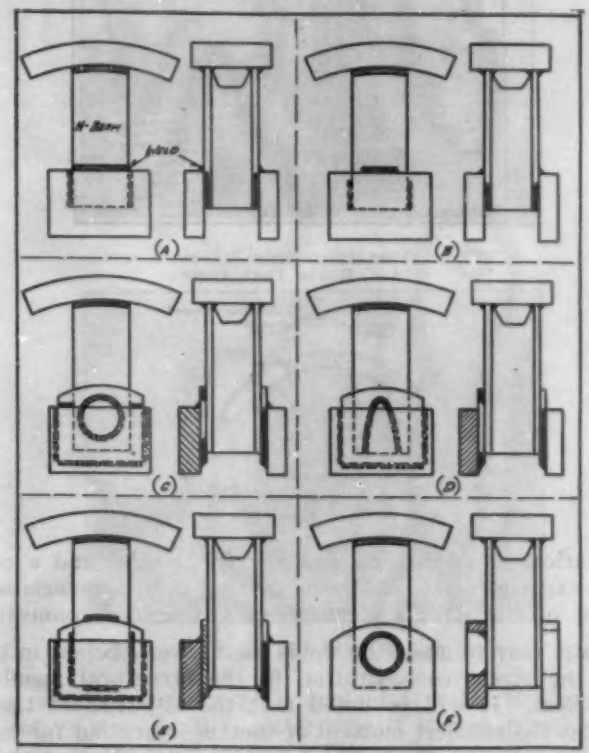


FIG. 5—SPECIMENS TESTED ON VIBRATION MACHINE

joint (b) (where stress must always be compared with shear stress failure, while in (a) the much higher value of tension failure can be approached), it must be noted that the energy of rupture of joint (b), is much larger than that for (a), and Dustin even goes so far as to favor

[8] H. Dustin, Congres International pour l'Essai des Materiaux, Amsterdam, 1927.

[9] Stress distributions of this type have been qualitatively studied by J. H. Smith, "Stress-Strain Characteristics of Welded Joints," JOURNAL OF AMERICAN WELDING SOCIETY, September, 1929.

(*b*) over (*a*) for dynamic loading. A conclusion like this, however, is clearly a case of balance of ductility of break against allowable stress.

The design of machines to be constructed of structural shapes welded together involves a great many factors in addition to the direct stresses in the welds. Fig. 4 shows the type of construction widely used for a-c. generators and motors, the rotors of which are direct connected to geared machines or combustion engines. These machines are subjected to large

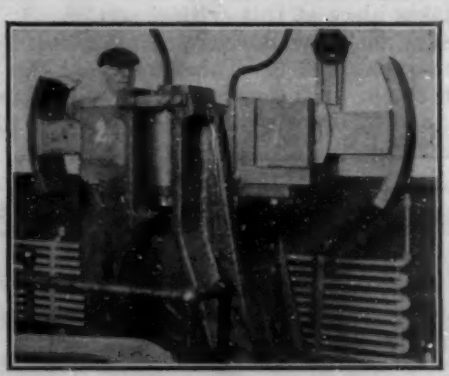


FIG. 6—VIBRATING TEST MACHINE WITH A-C. ROTOR TEST ARMS

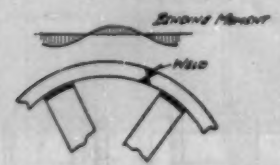


FIG. 7—WELD IN ROTOR RIM LOCATED AT POINT WHERE BENDING IS ABSENT

torque variations of both high and low frequencies and a considerable amount of experimenting has been carried out to determine the best arrangement of the structural members and welded connections.

It was quite easy to make the welds themselves efficient in these structures, but the stress concentration in the structural members was a serious problem. It will be noted that the H-beams of the rotor are placed so that the smallest moment of inertia is utilized for torque loads. This arrangement calls for larger beams but gives the most economical design to keep stress concentration at a minimum.

Fig. 5 shows several methods of fixing the H-beams into the hub of the rotor which were tested on the machine shown in Fig. 6. This machine subjected the specimens to a very violent oscillating vertical motion corresponding to torque oscillations in the actual rotor. Specimen (*c*) proved to be the best, but specimen (*b*) has proved satisfactory for normal application. Further tests are being conducted on a machine which will give actual as well as relative values of the stresses en-

countered and will also permit the superimposing of initial stresses in the structure which are independent of the varying stresses.

The initial stresses which are encountered in welded structures proved to be very harmful when the structure is subjected to varying stresses as discussed earlier in the paper. These initial strains are caused by the actual shrinkage of the weld metal itself and by the unequal heating of the various parts of the structure while being welded. Bending and

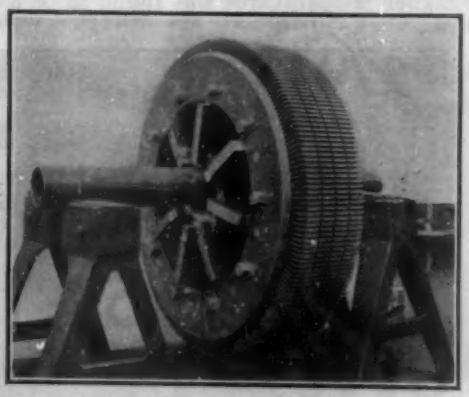


FIG. 8—1000-KW. ARC WELDED D-C. ROTOR

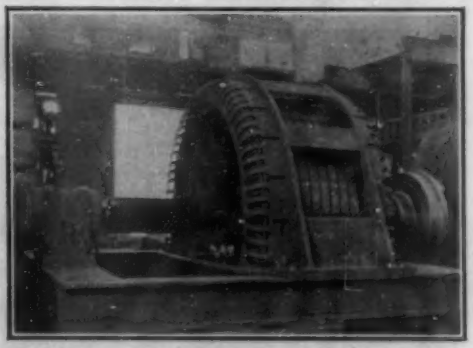


FIG. 9—ARC WELDED SINGLE-PHASE STATOR

twisting strains are set up while cooling to room temperature. Many complete rotors were built to determine if it was possible to obtain a structure free from initial strains. The method used in determining the residual strains was to drill small gage holes in the pieces before being assembled and recording the variations in the distances between them after being welded. After the rotor was completed, additional strain gages were clamped to the structure at various places and the individual members cut loose from the structure by hack saws. Various welding sequences, peening of welds, artificial cooling of members, and jigs were used, but it was found to be commercially impracticable to obtain a complete rotor free from high residual strains.

Annealing was then adopted in order to remove the strains and tests were made at various temperatures by our Research Dept. It was found that practically all residual strain was removed at 1000 deg. Fahr. and this temperature was adopted for all welded apparatus where a strain free condition is necessary. Several complete rotors were annealed at 1000 deg. Fahr. and the residual stresses found to be under 1500 lb. per sq. in.

Annealing at higher temperatures was found to be undesirable because

FIG. 10—2500-KV-A. LOWER WATERWHEEL BRACKET

FIG. 11—TWO WATERWHEEL BRACKETS UNDER TEST

of the greater liability of warping and cracking the welds. All of the physical properties of the weld itself are decreased by high temperatures and because of this it is not considered practicable to obtain refinement of the grain structure of the parent metal adjacent to the weld at the expense of the weld itself. These results concur with previous conclusions of other investigators.[9, 10]

It is of interest to note the design consideration necessary in the use

[10] J. B. Rose, JOURNAL OF AMERICAN WELDING SOCIETY, September, 1929.

of butt welds for the rims of the above mentioned rotors. These rims are made of bar stock rolled up and butt welded. It was at first thought desirable to locate the welds of one of the rotor arms across the butt weld in order to reenforce it but the bending and tension stresses were above our allowable limit. The location of the weld as shown in Fig. 7 at a point where the bending in the rim is zero and only the centrifugal tension exists, made it possible to use a welded construction.

In Fig. 8 we have a typical arc welded d-c. rotor, 1000-kw., 300-rev.

FIG. 12—300-HP. BLOWER PROPELLER

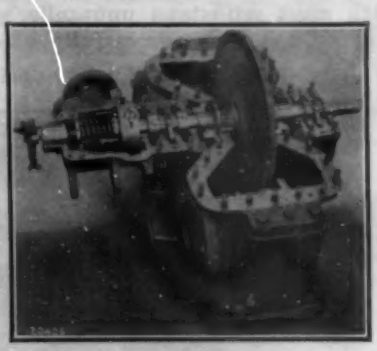


FIG. 13—ARC WELDED LASHING FOR TURBINE BLADES

per min. for steel mill application. The construction here is characteristically different from the a-c. rotors in that there is no welded connection between the spokes and rim, thus eliminating the condition where locked up stresses are serious. This permits the use of welding without strain annealing and has been applied with complete success to Diesel driven generators, steel mill drives, ship drives, etc., all of a dynamic stress type. All machines of this type have been tested at repeated short circuit and maximum overspeed, and are designed to withstand a torque load of ten times normal.

Fig. 9 shows a welded single-phase machine in which the varying stresses imposed have as serious an effect on the stator as on the rotor. This type is subjected to 200 per cent torque pulsations at twice the impressed line frequency.

Fig. 10 shows an arc welded bracket for supporting the rotor of a 25,000-kv-a. waterwheel generator. This type of bracket must be designed to permit a very small deflection and must withstand varying and shock loads. The waterwheel sets up considerable vertical vibrations and under certain operating conditions water surge impacts can be so severe that the rotor is actually lifted from its thrust bearing. Fig. 11 shows two brackets being tested for deflection by pulling them together with a through bolt. The tests showed that the deflection of the welded brackets is comparable with the corresponding cast design and can be predetermined with accuracy. The purpose of the bolted joints shown is to permit the dismantling for shipment. A considerable number of brackets of this general type have been in use for some time.

Fig. 12 shows the propeller[11] of a large volume high-pressure blower which is directly driven by a 300-hp. 3250-rev. per min. induction motor. It is constructed by arc welding the two blades into a slot out in the hub. Various strength and fatigue tests were made on this design and it has withstood severe service conditions. The entire blower housing is fabricated by arc welding and in some applications the propeller is driven by an all welded steam turbine.

Fig. 13 shows the application of arc welding for turbine blade lashing which must withstand unusually severe vibration stresses. This construction has been successfully used for several years.

Fig. 14 shows a welded cab underframe for a Diesel electric locomotive.

FIG. 14—UNDER-FRAME FOR DIESEL ELECTRIC LOCOMOTIVE

It has successfully withstood the severe bumping and twisting strains imposed by yard switching service.

Our company has also used arc welded designs successfully in the following applications which are subjected to dynamic stress conditions:

Crane structures.
Marine reduction gear units of several thousand hp.
Trolley pole bases for street cars.
Various ventilating fans.
Lifting lugs on various apparatus. Elevator cages and equipment.
Railway motor housing and gear cases.
Locomotive equipment supports.
Railway bridges.
Crank cases for high speed railway Diesel engines.

We have emphasized, in this paper, the degree to which electric welding may be relied upon in applications where the structure is subjected to dynamic stress. Such applications can be successfully made by giving due consideration to the factors of maximum working stress, residual welding stresses and stress concentration. The pessimism of the past few years regarding dynamic applications is slowly disappearing and it is only by the careful consideration of all factors that arc welding will be extended to all types of fabrication without restriction.

[11] Detailed Description, *Power*, July 23, 1929.

Welding Stainless Steel and Monel Metal*

BY M. E. OLSEN†

OUR firm has for many years been in the business of manufacturing equipment for dairies and ice cream plants. There have been some revolutionary changes in the equipment used by such plants during the past ten years. There are several reasons for this. One is the necessity of labor-saving equipment to handle the production and dis-

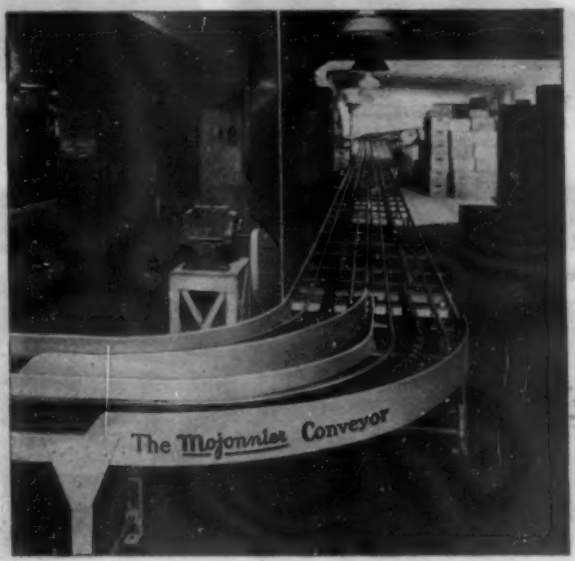


FIG. 1—MAJONNIER MODEL B, DOUBLE TRACK CONVEYOR. WELDED CONSTRUCTION USED EXTENSIVELY IN THIS PRODUCT

tribution of milk and milk products on a mass production basis. Another is the demand on the part of the public for high standards of sanitation in such plants. Therefore, the products manufactured in our plant can be divided into two classes. First, those whose purpose is that of providing an aid to mass production. Second, those whose purpose is to safeguard the health of the public in the packaging and delivery of milk products. It is in equipment of the latter class that stainless steels and monel metal are used extensively. It is common knowledge that these alloys show a great deal of resistance to corrosion by various acids and chemicals. Therefore, they provide containers for milk and milk products

*Paper presented before Chicago Section, A. W. S., January Meeting.

†Welding Supervisor, Mojonnier Bros., Chicago.

which do not involve any danger of chemical action, and which are strong enough to resist the stresses which might possibly be set up by shocks or by expansion and contraction in service.

In the fabrication of this equipment welding is practically a necessity. It is the only way in which we can secure an absolute freedom from seams. Any other method of joining would not leave the smooth, un-

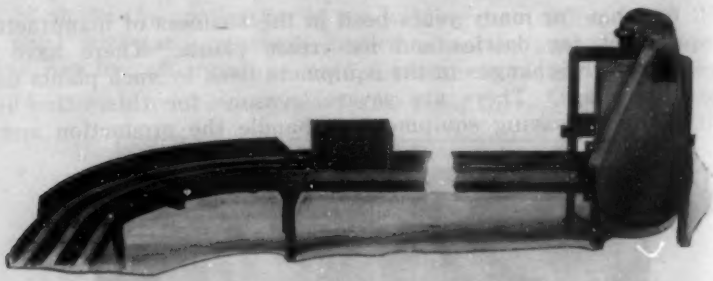


FIG. 2—BOTTLE CASE CONVEYOR

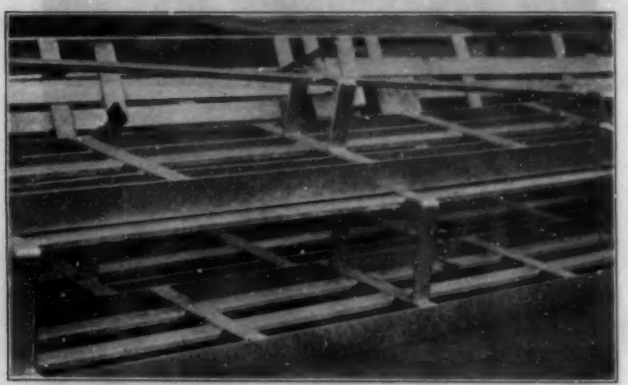


FIG. 3—HOW WELDING IS USED IN CONVEYOR OF FRAMEWORK

broken interior which is obtained by welding and which is entirely free from small cracks or crevices. It would be needless to try to tell a group of experienced welders of the many advantages of the process. In the manufacture of milk machinery, welding enables us to produce a superior type of equipment with the least manufacturing cost. This paper will tell what processes are used, what technique is followed with each process on each metal and a number of photos will illustrate the applications of these processes.

Before entering into the discussion of the work on stainless steel and monel metal, it might be well to indicate that our welding operations are not confined to these materials. We have to weld practically every commercial metal. We have a good volume of steel welding in the manufacture of our conveyor equipment, the frames, gear guards, etc. We

use welding extensively in the construction and maintenance of our own plant equipment. We have made cranes, chutes, shelving, storage bins and a complete sand blasting equipment by welding.

The processes used in the fabrication of stainless steel and monel products include oxy-acetylene welding, electric arc welding, spot welding and soldering. In some cases these are used in combination on the same product. The procedure adopted for the fabrication of any one piece of equipment depends, of course, on the service which is expected of that equipment. In some cases there is need for very little strength; but it is most essential that the seams be tight and smooth. In other cases there is a considerable amount of pressure involved, and joints must be 100 per cent strong as well as absolutely tight and smooth.

The stainless steel used most extensively is Allegheny metal, in thicknesses from 16 gage to 10 gage. When arc welding seams in this material, a ¼-in. thick chilling bar of copper 2 in. wide is placed beneath

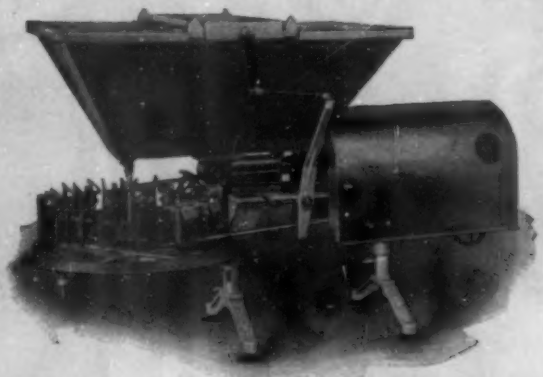


FIG. 4—ICE CREAM PACKAGING MACHINE

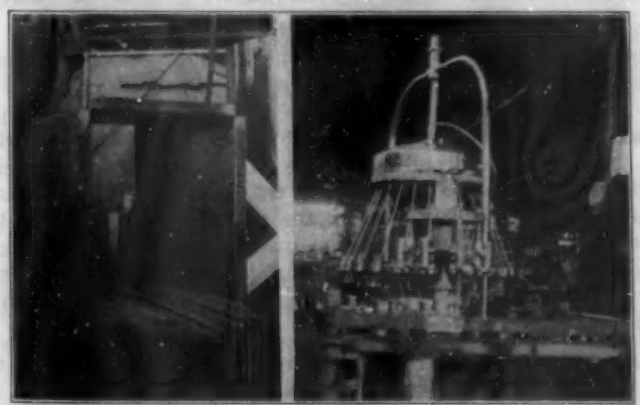


FIG. 5—DETAIL OF DOOR CONSTRUCTION

FIG. 6—MILK BOTTLE FILLER

the joint. A coated Allegheny rod is used with straight or reversed polarity. A ⅛-in. rod is used for 10-gage work with 52 volts and 150 amperes. Fifty volts and 100 amperes gives about the right setting for the lighter gages, a 3/32-in. electrode being used. Best results are secured when the operator acquires the knack of advancing the weld straight ahead along the seam without any weaving motion; that is, the weld is not puddled as in steel welding. Most of the stainless steel welding in our plant is done with the electric arc. When the torch is

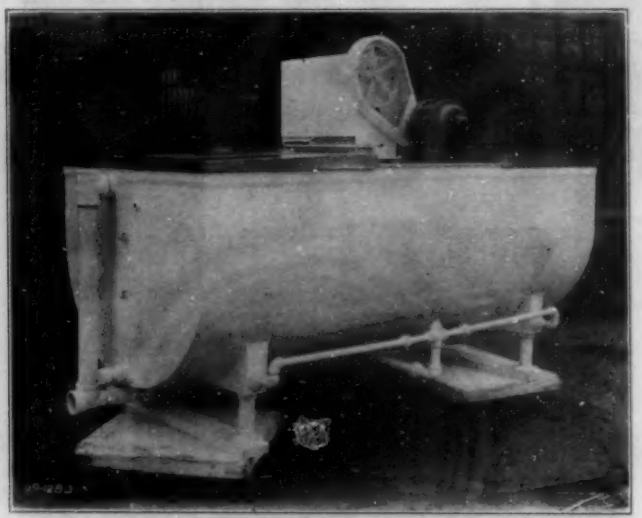


FIG. 7—WELDED MILK PASTEURIZER

used, points to watch are: 1st, to be sure that the flame tends toward a carbonizing rather than an oxidizing flame; and, 2nd, to go straight ahead, using as little heat as possible to secure the necessary penetration.

The arc-welding procedure for monel metal is somewhat different. The material used is from 20 gage to 10 gage. For practically all of this work we use a ⅛-in. processed monel metal wire with reversed polarity, 50 volts and about 150 amperes. The weaving motion which is so commonly used on steel welding should not be used with monel metal. The best deposit is secured by working the electrode in a vertical plane with something of a dipping motion, the purpose of this being to allow the operator to place each new molten drop of the electrode directly into the melted puddle beneath. When this is done there is very little spattering and no overflow of electrode material onto metal which has not melted.

With the oxy-acetylene torch monel metal sheets are welded without the use of flux. A bright monel metal welding wire is used and a somewhat heavier flame than we would use for welding steel of the same thickness. More care has to be used to avoid drafts than in the case

of steel, and the weld has to be built up well above the surface so that there will not be any low spots or porous spots when the top of the weld is ground off. Backing plates or jigs must be used to prevent buckling along the edges of the seam and the weld should be made as rapidly as possible. If the work does not go rapidly, it can be speeded up somewhat by using a little borax brazing flux. It is not always necessary or desirable to weld a complete seam. In some pieces of equipment the seam is prepared by tacking together with solder with

FIG. 8—INTERIOR OF MILK PASTEURIZER

1-in. tacks 6 in. apart; then 1-in. tacks are made in the center of the space left by arc welding. These arc-welded tacks furnish sufficient strength to hold the seam together. The tacks are then ground off even with the surface, then the entire seam is soldered.

The reason we weld is that we found soldering only gave an unsatisfactory result as to strength. We, therefore, tack weld for strength and solder for finish. There is absolutely no mystery attached to the welding of either Allegheny or monel metal. All one requires is a fair

amount of skill and a carload of common sense, which, in the final analysis, is all that is required to weld any metal or metals that are available.

A few words as to the gas method with monel tubing. We merely weld the edges together from the outside. In this way we avoid getting metal on the inside and prevent the difficulty of extra grinding and buffing, especially on long lengths. We solder the inside of tubes to form a smooth finish.

The reason we gas weld tubes instead of using the electric method is a problem of costs, there being less grinding when this method is

FIG. 9—MILK TESTER

employed. We also use gas welding extensively in reclaiming castings from our foundry and also for welding light sheet iron work.

In our problems we use the electric arc a great deal more than the acetylene in welding Allegheny metal because of better control over the heat, and we don't have to contend with an excessive amount of expansion and contraction.

Sometimes spot welding is used for tacking instead of arc welding. This is only possible when we can get at both sides of the seam readily with the spot welder, which is equipped with water-cooled electrodes.

I will now compare a few cost figures which of necessity will be limited, taking into consideration the short time they have been available.

The three-foot Allegheny vacuum pan had a total of 300 lineal feet of welding. Total welding time, 35 hours, which does not compare adversely with the figures for steel.

A comparison of our production cost of power units since welded construction was adopted as compared with previous production cost

has shown a 35 per cent saving. The production cost of the welded sections of the conveyor systems compared to the production cost of riveted design indicates a saving of 50 per cent. The savings obtained by welding of the hoppers are reached mostly by the fact that the cost of repair work on hoppers in service is eliminated. There is a 50 per cent saving in welding the doors shown as compared to previous fabri-

ALLEGHENY METAL

C ..... .20%
Mn .... .50%
Si ..... .50%
S ..... .025%
P ..... .025%
Cr .....17.00 to 20.00
Ni ..... 7.00 to 18.00
Balance Iron

ASCOLOY 33

C ..... .12%
Mn ..... .50%
P ..... .025%
S ..... .025%
Si ..... .50%
Cr .....12.00 to 16.00
Balance Iron

ASCOLOY 44

C ..... .20%
Mn 1.00%
S ..... .025%
P ..... .025%
Si ..... .50%
Cr .....22.00 to 25.00
Ni .....10.00 to 13.00
Balance Iron

ASCOLOY 55

C ..... .25%
Mn 1.00%
S ..... .025%
P ..... .025%
Si ..... .60%
Cr. ....26.00 to 30.00
Ni ..... .60%
Balance Iron

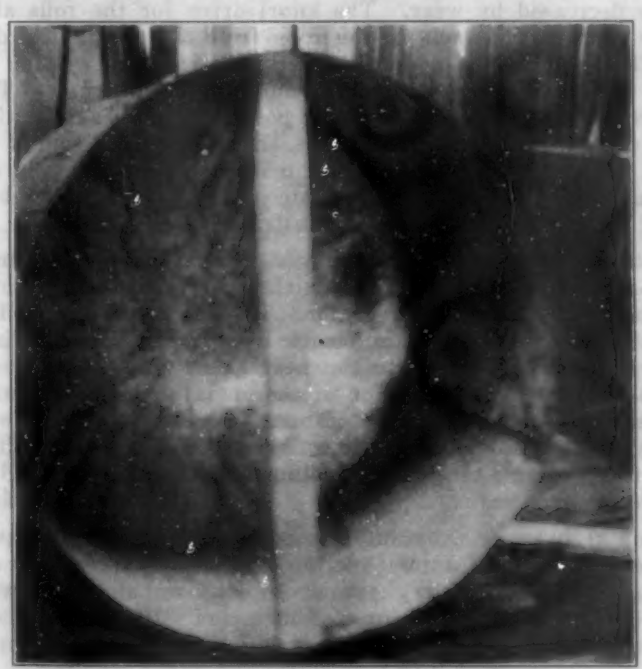


FIG. 10—SHELL OF HAT WELL (STAINLESS STEEL)

cating methods, which were mostly wooden construction, and at the present time the apparent saving through welding in the entire factory is about 35 per cent on those items which are fabricated with these processes. This is enough to show that we have real good business reasons for using welding in the manufacture of this equipment.

Resistance Seam Welding in 1929

W. H. GIBB†

MANY new developments in the process of resistance seam welding, both in the machines themselves and the adaptability of work for seam welding by large manufacturers of automobiles, refrigerators, paint pails and containers, were the outstanding items of the closing year. Close cooperation between the builder of seam welders and the user added greatly in these new developments.

1. The seam welding of terne plate, brass, aluminum, and other non-ferrous materials such as Everdure and Ascoloy, in extensive production featured many installations.

2. The most important development in the seam welders during the past year is the knurl drive for the welding rolls, which maintains a constant welding speed and a constant welding face on the rolls as the diameters are decreased by wear. The knurl drive for the rolls also separates the electrical contacts to the rolls from the mechanical drive for same. The knurl, being mounted directly opposite the welding point of the roll, counteracts the welding pressure on the bearings. This is a very good feature as it eliminates any possibility of the rolls sticking or slipping over coated stock. This was the result most sought for and obtained. Knurl drive seam welding machines are absolutely essential to economically seam welding terne plate gasoline tanks and high production in the barrel manufacturing industries.

3. Automatic and semi-automatic resistance seam welding machines were developed to a high state during the past year in the manufacture of condenser plates for a refrigerator. The flat grooved plate is loaded on an elaborate fixture on the automatic machine and the machine welds in parallel grooves, indexing to the next groove on the return stroke, continuously without the attention of the operator until sixteen grooves are welded. The fixture is mounted on a slide and drawn between two stationary welding rolls by means of an hydraulic cylinder. The hydraulic equipment also operates the upper welding roll vertical stroke and indexes the fixture for each seam.

4. Many highly special machines were developed during the past year such as seam welding of automobile brake shoes, stamped brass radiator forms for dwellings, hosiery forms, simplifying and improving the products beyond any other form of fabrication. Heavy gages of stock were seam welded on production for the first time in the history of resis-

†Vice-President, Thomson-Gibb Electric Welding Company.

tance welding. The installations were used for range boilers, railway car heaters, transformer cases, etc.

5. The one item that has made seam welding possible and caused its general acceptance to the trade might be said to be the use of the current interrupter on all seam welding except tube welding and some forms of high speed work. The interrupter permits a much wider range of perfect seam welds so that a handling speed of 3 ft. up to 21 ft. per minute of welding can be obtained without burning or allowing the stock to cling to the welding rolls. Interrupting the welding current has been found necessary for welding of non-ferrous and coated stock and the heavier gages, and it will improve the weld on all work seam welded.

6. Improvements on transformers, contact bearings, quick change of welding rolls, quick changing of welding speeds, more universal welding roll mounting, are the outstanding features that have been added to standard seam welders, making them easily adaptable to many sizes and shapes of work.

7. An item that must not be forgotten in the installation of seam welding is the service rendered by the machine manufacturer. Most installations are made on new work and with new operators, and as seam welding is far more precise and needs closer attention at the start of production than the familiar spot welding operation, close cooperation between the machine builder and the user is necessary for a successful installation.

Large Scale Ornamental Work

DE W. ENDICOTT†

THE beauty and utility of hand wrought ornamental iron objects has long been appreciated everywhere, but large scale production has been difficult due to the extensive labor required in the fabrication of such objects. Aided by the oxyacetylene process, large scale production is now possible to meet the great and growing demand for such objects. The present vogue is being supplied largely by manufacturers who have found the industry profitable because of the speedy production possible with the use of welding. In the past, antique pieces of ornamental wrought iron were fabricated by making blacksmith or forge welds on heavy gage metal, which necessitated considerable manual labor as well as unusual skill for the finer work. The design for work of this sort had to conform in its complexity to the skill of the worker on the anvil.

The use of oxy-acetylene welding in making the joints in ornamental metal increases rather than lessens the beauty of the finished object. Today artistic objects fabricated from wrought iron, Monel metal, bronze, copper, brass and other special alloys are nearly always of welded construction. The modern metal artist knows that this weld is stronger.

†Technical Publicity Dept., Linde Air Products Co.

requires less labor and presents a much finer appearance. The crudity of antiques was due to the limitation placed upon the metal worker rather than to any choice of the artist. The artist today, with the aid of welding, obtains an appearance of antiquity by means of the oxy-acetylene flame, and does so quickly and economically. Artists frank-

FIG. 1—WELDED WROUGHT IRON PORTE-COCHERE

FIG. 2—ORNAMENTAL METAL DOORS IN THE HOME OF A COLLECTOR

FIG. 3 — HAND-WROUGHT METAL GRILLE WITH VARIETY OF WELDED JOINTS

ly admit that designs made today could not be executed without the use of the oxy-acetylene process for making the complicated metal joints.

A large company in the Middle West has been engaged in the fabrication on a production basis of many items of large size. By the use of the oxy-acetylene process, they have been able to design and fabri-

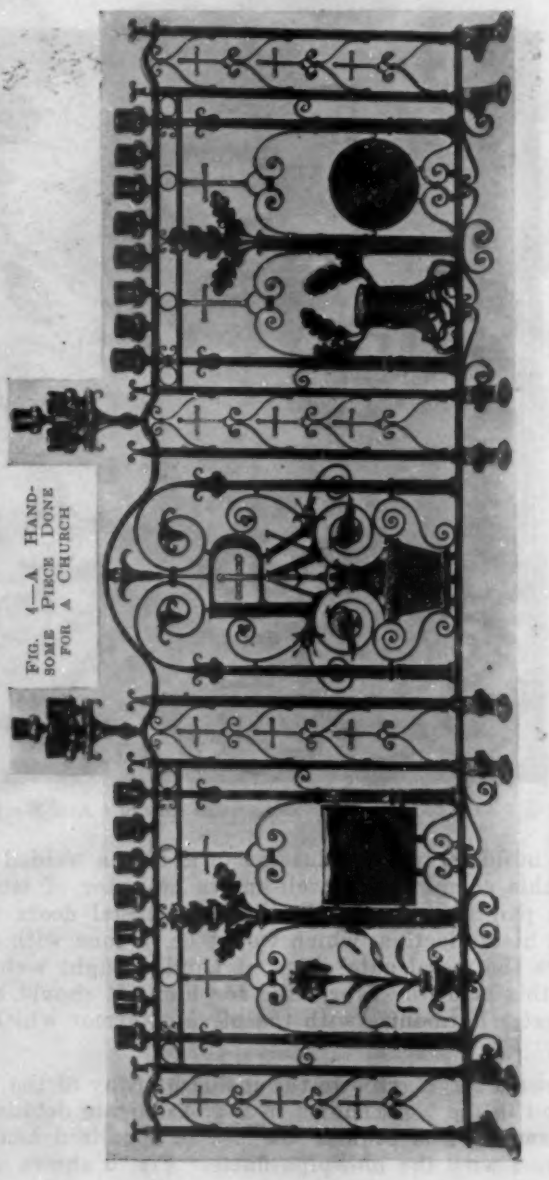


FIG. 4—A HANDSOME PIECE DONE FOR A CHURCH

cate from heavy metal large grilles, gates and arches and at the same time preserve intricacies of design which would not be possible were any other method used. This company has combined perfect artistic taste with efficient fabrication on a large scale basis. Fig. 1 shows a hand-wrought iron porte-cochere which this company designed and erected for a private city residence. The balcony railing on the second

FIG. 5—PEACOCK PLUMES AND OTHER DETAILS ALL WELDED

floor of the building in this illustration is also a welded product fabricated by this company. A well-known collector of medieval armor and antique paintings was anxious to have metal doors for the room that housed his collection, which would be in tone with the antiques. Fig. 2 shows the metal gate doors of hand-wrought welded construction which this company fabricated for him. It should be noted how well these gates harmonize with the piece of armor which is standing at the right.

Fig. 3 shows a large grille in the inside hallway of the building. In this work and in the work shown in Fig. 4 delicate details such as the petals and small birds require the use of localized heat such as is easily obtained with the blowpipe flame. Fig. 5 shows another piece

of work. This is a close-up of a wrought iron panel and clearly shows the number of places where welded joints are required. The peacock plumes are especially noteworthy from the metal working point of view.

Fig. 6 shows one of the most elaborate pieces of work which this com-

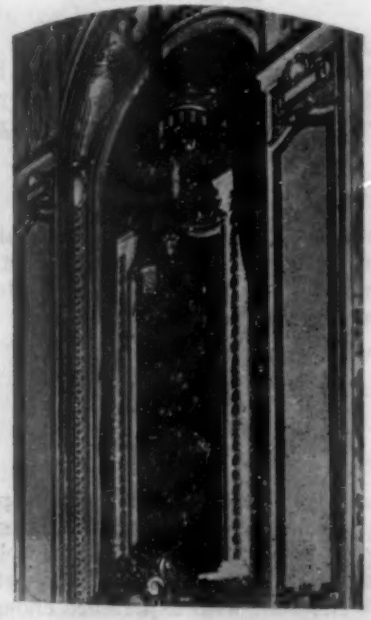


FIG. 6 — HAND-WROUGHT AND WELDED MURALS FOR LARGE MOVING PICTURE THEATER

pany has recently done. It is the welded ornamental metal mural panel in one of New York's largest motion picture theaters. It is remarkable for its minute detail. It shows the possibilities which this type of work has in the decoration of building interiors.

Four Years Experience with Structural Welding*

A. L. WILSON†

THE use of welding in the structural field has increased steadily in the last four years. During that time I have been employed by the Mississippi Valley Structural Steel Co. Most of my time has been spent in working out ways and means of adapting welding to structural work in a practical way.

Welding Versus Riveting

The late Professor Ira O. Baker of the University of Illinois defined engineering as the directing of human endeavor in the use of materials of nature for the benefit of mankind. He went on to say that the way to approach an engineering problem was to:

1. Find out just what you have to accomplish.
2. Find out how many ways it can be done.
3. Find which is the best way.
4. Do it that way.

We need to approach welding as an engineering problem. The retarding factor in the advancement of welding in the structural field is the lack of logical study of each problem. Can you weld it? Can you rivet it? Considering time allowed to fabricate, strength and cost which is the better? Where's the man with experience enough to tell you?

We have had in the past the militant advocate of welding who said that in five years there would be no rivets driven. This man would look at the plans of a job and say off hand, "Weld the whole thing."

Then on the other hand we had the man who thinks that welding is a glorified method of soldering.

We not only had them, we still have them.

What we need is men with a good supply of horse sense, a thorough knowledge of welding and its adaptability together with an accurate conception of shop costs. Then by studying the different types of work on the job with an open mind they can decide where welding would be of advantage either by itself or in conjunction with riveting.

The man in the shop is most likely to understand the adaptability of welding. He will undoubtedly have the greatest faith in it. But beyond his belief in it he must understand the changes in design necessary to make welding show a profit. Then he will have to do the pioneering work with the engineer and the draftsman.

---

*Paper read at Nov. 7, 1929, meeting of A.W.S.

†Mississippi Valley Structural Steel Co., Melrose Park, Ill.

You can not take a riveted design and simply weld it together instead of riveting it and save any money or even do it as cheap.

We have one class of jobs that call for welding. These are the jobs which for some reason are not adaptable to riveting. I have in mind two jobs that come in this class.

One was the seats in the Harmon Stadium.

It was required to build some portable seats for the new Chicago Stadium on Washington Boulevard. One night there would be a prize fight at which the seats would be used and a couple of nights afterward they would have a hockey match and require the floor cleared. To do

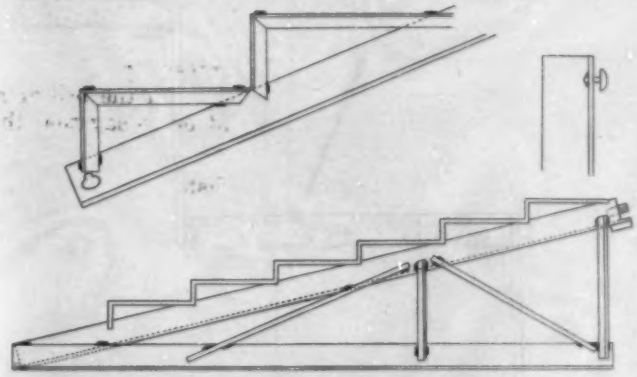


FIG. 1—GENERAL FEATURES OF DESIGN FOLLOWED IN CONSTRUCTION OF PORTABLE SEATS FOR THE HARMON STADIUM. THE SMALL SKETCH IN THE UPPER RIGHT HAND CORNER SHOWS HOW A WELDED STUD IS PROVIDED FOR ASSEMBLY, THIS STUD FITTING INTO THE SLOT SHOWN AT THE BOTTOM OF THE SKETCH AT THE LEFT OF THIS

this the seats had to be put on supports that would be light and also that could be stored in a small space. A riveted job with the connecting clips and gussets was bound to be heavy and more or less cumbersome. On this job there was forty-five tons of welded seat supports. Besides giving better visibility the main floor seating capacity was increased six hundred seats.

Another such case was the riser plates in the balcony of the Freeport Masonic Temple. The riser plates for this balcony were curved and exposed requiring a perfectly smooth job. To get the kind of a finish the architect wanted the rivets would have had to be countersunk and chipped and then ground. There were about two hundred of these plates. We bent the angles, and pulled the plates to them in a jig we welded out of scrap.

Savings Effected By Welding

It is one thing to have the advantages of welding pointed out after the job is done and another thing to find them before the job is started. The fundamental requirement of any process is that it shall be as good as another and at the same time cheaper.

There are two items to the cost of a structure, the material and the labor.

On an average I believe that you can save about one-seventh of the weight by welding. This saving comes in three ways.

In tension members you do not have to allow for the metal punched out. In the case of trusses that would permit you to use the next smallest angle in many cases. That is, if you need a 4 by 4 for riveting you might use a 3½ by 3½ angle for welding.

There are a great many pieces that are much bigger than they need to

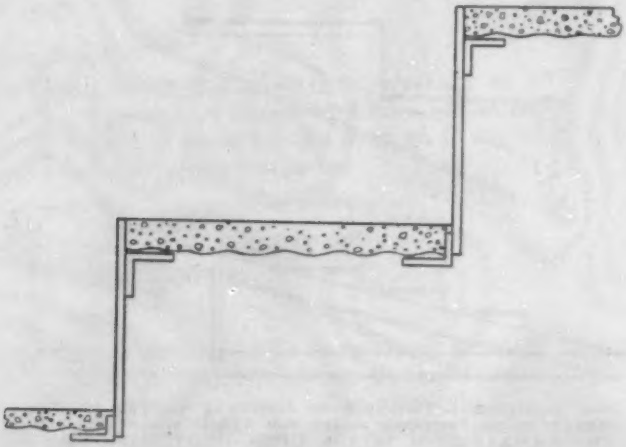


FIG. 2—SCHEMATIC DRAWING OF CONSTRUCTION OF RISER PLATES IN THE BALCONY OF THE FREEPORT MASONIC TEMPLE. IT IS OBVIOUS THAT WITH THIS TYPE OF CONSTRUCTION A SMOOTH FINISH CAN BE PUT ON THE OUTSIDE WITHOUT GRINDING

be for strength merely to have enough room to get the rivets in. In the case of welding you can cut these down.

The third saving has not been used much as yet. This is the possible saving due to continuity. That is, if you weld a beam to a column and one right opposite to it on the other side of the column you can consider that the two beams act as one continuous beam. This permits the use of a smaller beam. Then, too, in the case of welding you can consider beams as having an absolutely fixed end which will reduce the bending moments and in turn the size of the beam.

It often happens that the only saving you will get by welding is the saving in material, but this is worth while.

In order to take advantage of welding the designers and draftsmen have got to be "welding minded." They have had the methods and details of riveting drilled into them for years and they have a tendency to make welded pieces the same way—merely putting a couple of inches of weld on in place of a rivet.

In considering the savings in fabricating possible by welding you need a thorough understanding of the different steps in producing the finished piece. Because you have one man welding and four men on the rivet gang doesn't mean that the cost of welding will be one-fourth of the cost of riveting.

In the usual course of fabrication the steel has to be marked, punched, bolted up, and riveted. It has been my observation that if you can save sending a piece to the bolt up and rivet floor you will be able to weld it at least as cheaply as you could rivet it. And if you can add to this

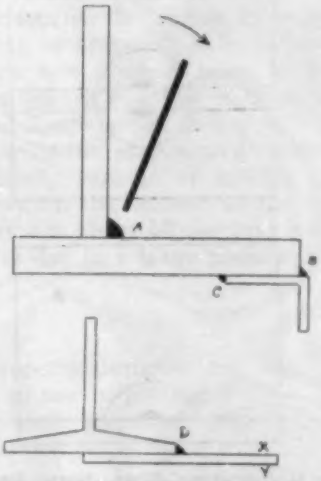


FIG. 3—ILLUSTRATING STRONG AND WEAK FEATURES OF FILLET WELDS. ROTATION OF THE TOP PLATE IN THE DIRECTION OF THE ARROW WOULD CAUSE FAILURE OF THE WELD AT "A." HEAVY BLACK LINE INDICATES PROPER SLANT OF THE ELECTRODE. THE SMALL TACK WELD AT "C" WILL PREVENT WELD "B" FROM BEING BROKEN BY ACCIDENTAL BENDING IN THE WRONG DIRECTION. A BLOW ON THE LOWER PLATE AT "X" WOULD NOT INJURE THE WELD "D," BUT A BLOW AT "Y" WOULD EASILY BREAK IT

the saving you get by not marking or punching it, that is, send the steel direct from the cutting department to the welders and let them fabricate it you will in most cases show a saving by welding IF—IF there is some simple way of placing the pieces in their proper position and holding them while you do the welding. There are many cases where the making of jigs to hold pieces while they are being welded offsets the other advantages of welding them.

That is one decided advantage that riveting has over welding. You can bolt the pieces together and partly tighten the bolts and then drive the pieces exactly square or to the right bevel. In welding you have to hold the pieces together with clamps and they tend to slip if you try to

drive them. If there is a quantity of one kind you can usually make a jig out of scrap pieces to hold them.

Designing for Welding

Then you have certain definite savings on special operations. Take the matter of countersinking and chipping rivets where a smooth surface is required. In most cases a way can be devised to weld the pieces in such a way that the countersinking and chipping is avoided. A great many sharp bends or difficult twists that take a long time to blacksmith

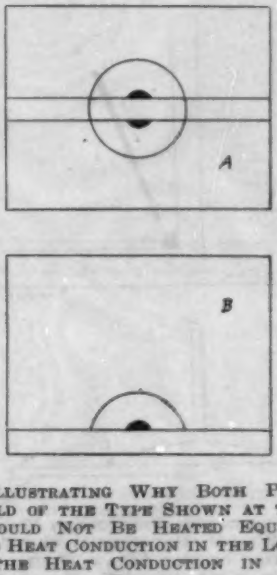


FIG. 4 — ILLUSTRATING WHY BOTH PARTS OF A FILLET WELD OF THE TYPE SHOWN AT THE TOP OF FIG. 3 SHOULD NOT BE HEATED EQUALLY. "A" SHOWS THE HEAT CONDUCTION IN THE LOWER PLATE AND "B" THE HEAT CONDUCTION IN THE UPPER PLATE

can easily and cheaply be avoided by welding two or more separate pieces together, or by burning or cutting out a notch and after the piece is bent welding the crack up.

In the case of elbows in flues you save the expense of laying out the holes and punching them in the plates before they are rolled. Unfortunately unless you have a lot of work of this type it takes quite a while to get the holes so that they come exact after you roll the pieces. It is fairly easy to make elbows by welding even up to 10 and 12 ft. in diameter. There is a little trouble in lining the sections up which would be avoided if you had bolt holes. Probably the most economical way to make flues is to weld the elbows and rivet the straight sections.

To summarize the matter of designing for welding: you can start with a riveted design if you wish and study it to eliminate metal used merely to provide connections for riveting; eliminate several handlings of a piece when it can all be done at the welders; eliminate special work that

costs extra; then don't try to weld something that can be made cheaper and better riveted.

Strength of Welds

We have not as yet considered the design of welding from the strength standpoint. There is just one point that is fatal from a strength standpoint, that is, designing your welds so that you get a bending against the weld instead of having the weld in tension or shear or compression. This has to be taken into consideration not only as regards the stress on the piece after it is erected, but also any stress it may get in shipping or erecting.

For a unit stress value of welds for use in estimating the amount of weld needed the best way to arrive at it is to have your welders make some welds and then see how much it takes to break them. We use a 5/16 bead in most of our work and find it holds from 5000 to 7000 lb. per lineal inch. You can compare test values with what your men get to see how they compare with the experienced welder. If you use values that your men are actually capable of making you will always have enough and can cut down on the amount as the men become more proficient. Our welds today are about 50 per cent stronger than they were three years ago. This is due in a large measure to the improvement in the welding wire.

Production Methods

If you have work properly designed for welding the next thing to consider is the method to use in getting it out. You have to take into account material, equipment, operators, their training, means for holding the work, and inspection.

Our material at the Decatur and the Chicago plants is all under cover. It comes to the welding floor practically free from rust and requires no special preparation before we weld it.

Welding Apparatus

There are many good and satisfactory makes of welding machines. We have found the short arc machines better adapted to our work than the new machines that will carry a longer arc. The helmets that hinge up and over the head are best adapted to our work as it permits the operator to use both hands and by a shake of the head to bring the helmet down when he gets ready to start welding. However you want to be sure that you get one with plenty of head room as some of them bind the head or rub the ears. We make our own electrode handles. They are heavier than the ones on sale, but stand up a great deal better. By putting beveled grooves in the jaws we get a very firm grip on the wire. It also keeps the wire from twisting around if it sticks.

There is considerable argument about the effect of the flashing of the arc on workmen at or near the welding floor. We have very little trouble with flashing unless a man is working within 10 or 12 ft. of the welder. We have several movable sheet iron screens. We use either these or cardboard when the welders have to work close together. We have found

that if they wear a light weight pair of goggles under their helmet that it gives them better protection than screens when working near together. For fit-up men working around the welders any kind of goggles will protect them as long as they don't look directly at the arc. Several of us use our spectacles as protection by putting pieces of cardboard on the bows to keep the light from coming in the sides.

Laying Out the Work

For structural work you need a large plate on which you can make layouts, placing the pieces on the layout for welding. You will also need a floor of some kind to which you can clamp trusses, lintels, beams and struts, etc. This should be solid to permit pulling pieces into place. We have a very satisfactory floor made by laying 8 in. beams about 10 ft. long 3 ft. centers across two 9 in. stringers. If you run a line the length of the floor about a foot in from the ends of the beams and lines perpendicular to this one down the center of the beams you will save a lot of time in laying out frames and doors and so forth that require right angle corners.

You will find that you need clamps with a coarse thread, preferably a square thread as the little globules of weld mettle fly and stick to fine threaded clamps and very quickly put them out of commission.

We have found it best to train our own men. If you get hold of a welder who doesn't know how to weld but thinks he does, it is very hard to teach him much. Acetylene burners seem to be very adaptable as arc welders.

A man must be at ease to weld. If you can brace your knee or elbow against something it helps tc steady your body and reduce the strain of trying to hold yourself still.

Technique of Welding

For beginners especially, the cable should be drawn over the shoulder and just enough slack left to allow you to move the holder back and forth. The weight of the cable when resting on the ground gives a pull on the wrist as you move the electrode handle that interferes with holding it steady.

It is very hard to tell what path the current will take. Sometimes you should weld toward the "ground" and sometimes away from it. The surest rule is to always follow the little ball of flame at the end of your wire. If you hold a short enough arc you will see a little ball of flame that tends to go one way or the other. If you follow this you will get a good, clean, sound weld. The reason for following the flame is that as it proceeds the actual deposition of the weld metal it heats the base metal up to a considerable extent before you come to it. The actual manipulation of the arc is much easier when following the flame.

Another point in welding is to keep the wire moving slightly from side to side even when you do not require a large enough bead to require weaving the weld. If you are welding in a corner and try to hold the wire steady and it swerves a little it may stick or it may get too

far away and break the arc. But if you have a constant motion to it you will draw it away before it has time to either break or stick.

In many welding operations the pieces to be welded are the same thickness, but in structural work they are usually of different thicknesses or you have the edge of an angle to weld to the center of a plate or flange of a beam. In other cases you have the edge of a plate to weld to the center of another plate. It is important to melt both pieces about equally and this cannot be done by playing the arc on both equally.

When welding light angles to beam flanges we play the arc on the beam

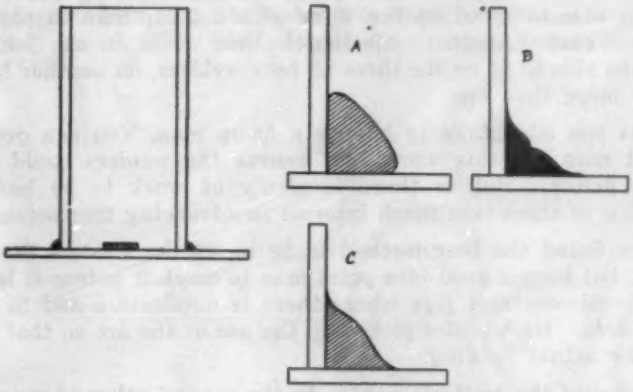


FIG. 5 (LEFT)—THE DESIGN OF WELD OF H-BEAM TO PLATE IN THE CONSTRUCTION OF COLUMN. FIG. 6 (RIGHT)—CROSS-SECTIONS OF DIFFERENT TYPES OF WELD DEPOSITS. "A" IS MADE WITH TOO LITTLE HEAT; "B" WITH TOO MUCH HEAT AND "C" WITH THE PROPER HEAT

near the toe of the angle and the angle heats up enough to melt without the arc being played directly on it.

If you can get a man who can hold a steady arc and will pay attention to his work to see that he is following the arc and playing it on the piece hard to heat you will in a short time have a good welder.

In the matter of heat it is a rather general idea that the larger the current used the better, as it gives more penetration. This may be true in the hands of an experienced man. However, it also permits the holding of a longer arc which gives a porous weld. This is often hard to detect in the finished weld.

I have been unable to substantiate the theory that a higher heat produces speed. On the other hand I did not find that it made a weaker weld when used by an expert welder. In welding structural shapes we find an amperage between 150 and 175 to give the best results with 5/32 in. wire.

Clamping and Tacking

When we consider the matter of fabricating structural steel we have one thing to contend with that a lot of other users of welding are free from. In the structural field a large number of the pieces are different

and each job is different. We cannot take a special operation and study it to eliminate lost motion and find the quickest methods of production except in a general way.

In the first place the main question is whether you are going to have a man clamp the pieces in place ahead of the welders or whether you are going to let the welders fit up the steel as they go along.

There are several objections to having a fit-up man. You have to have plenty of room so that he can fit up pieces in one place while the welder is welding them in another. The welder has to produce about twice as much work with a fit-up man as without to pay for having him. We have never been able to speed up the work with a fit-up man to pay for the added labor cost. Another objection is that while on one job a fit-up man may be able to fit up for three or four welders, on another he cannot fit up for more than one.

There is one advantage in having a fit-up man. You can get a good blue print man for this work. Of course the welders could learn to read blue prints. But as there is plenty of work to be had merely welding, few of them take much interest in advancing themselves.

We have found the best method to be to let the welders fit up their own work, but have a good blue print man to check it before it is welded, figure out and construct jigs where there is duplication and fit up complicated pieces. He has also picked up the use of the arc so that at times he does the actual welding.

As to some of the methods used: In the case of columns we mill both ends of the beam or H. We mark the center on the web and flanges and put the center lines on the plate. The welder then holds the plate on center while he tacks it with the other hand. Care must be taken to see that you have it tacked in enough places so that the weld in cooling will not pull the plate away on one side.

That is one thing that you have to look out for. When a weld cools it shrinks. If you weld all along one side of a piece without tacking down the other side when you get to the end you may not be able to get the other side pulled down. When you weld an angle frame to a plate to make a door if you do not tack it and then first weld one side and then the other the door is likely to warp.

In making beam and plate lintels we put the plates down on our welding floor and after the beams are set on top we clamp the two together wherever it is necessary to get contact. If a beam is sprung a little you can often clamp it over into place without sending it back to be straightened.

In making ladders we punch the holes for the rungs a sixteenth over size and cut the rods an eighth short. By using a stick of wood the proper length for a separator, we space the bars and tack the rungs then welding them on both sides of the bar.

In putting angles on the webs of beams or bars on the backs of channels edgewise the easiest way seems to be to pull them down and hold them while a welder tacks them. In pulling flues into place and plates up

against beams on bulkheads and dam gates you will have to weld some temporary bars on to give you a chance to pull the pieces together.

We use wooden blocks a good deal to get our spacing instead of measuring each time. The distance of an angle back from the edge of a channel or the distance of anchor bars on curb angles from the back of the angle can easily be measured this way.

Repair and Odd Work

Odd work for the welders consists in welding mispunched holes and flaws in the steel.

As castings and small parts break around the machines we find a way to replace a lot of them with welded scrap. Our blocks for bending,

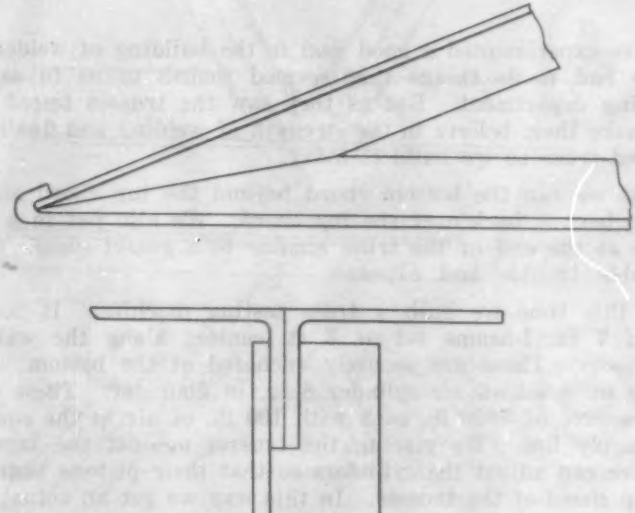


FIG. 7—TRUSS CONSTRUCTION SHOWN AT THE TOP WAS ABANDONED BECAUSE IT WAS FOUND ENTIRELY UNNECESSARY. THE LOWER SKETCH SHOWS THE END OF A WEB MEMBER SLOTTED TO SLIDE OVER THE CHORD

crimping and flattening are all made up out of welded plates. Some of the spacing tables on the punches are all welded and all of them are partly welded. The motor supports at the machines are mostly welded as it is very easy to clamp a platform to a column or hang it from a truss and after you get it in just the position you want it to weld it there. We weld small jib cranes for use over machines without having them drawn or laid out. In one case we wanted a 5 ton crane over an end miller. We just fastened the crane beams to the under side of a portal bracing and welded in enough more members to give a truss construction to the

bracing. We drill very few holes around the shop for maintenance work. It is easier to send a welder over to tack on whatever you want.

There is considerable argument pro and con as to whether a weld can be inspected. A good sharp blow with a 12 lb. sledge hammer right at the weld will break a poor weld. You can measure the weld with a gage to see if it is up to size. A good weld can be told, also a weld made by a long arc, too little or too much current. A long arc spatters the metal instead of depositing it at one point.

Part Two—Developments

Up to this point I have taken up welding as we find it in our regular routine. Now I am going back over some of the things we have developed in structural welding. It may save you taking the same steps.

Trusses

We have experimented a good deal in the building of welded trusses. We have had to do things that seemed foolish to us to satisfy the engineering department. But as they saw the trusses tested we were able to make them believe in the strength of welding and finally evolved the welded truss as we build it today.

At first we ran the bottom chord beyond the top chord and heated it up and bent it back over the top chord. We also put in a reinforcing plate at the end of the truss similar to a gusset plate. This was considerable trouble and expense.

About this time we built a truss testing machine. It consists of a row of 7 in. I-beams set at 3 ft. centers along the wall of the welding room. These are securely anchored at the bottom. On each column is mounted an air cylinder 8 in. in diameter. These cylinders give a pressure of 5000 lb. each with 100 lb. of air to the square inch in the supply line. By placing the trusses against the base of the columns we can adjust the cylinders so that their pistons bear directly on the top chord of the trusses. In this way we get an actual uniform load equal to about once and a half the design loading on a 40 ft. truss.

Instead of welding the complete joint at the heel of a truss which would amount to 15 in. we welded 3 in. on each side and then put it in the testing machine. The top chord humped up at the heel showing that there was plenty of strength without bending the bottom chord up or puting in a gusset plate. Since then we have left out the gusset plates except on trusses of around 80 ft. where they were required for vertical shear.

Another argument advanced by the engineers was that if we put the diagonal web members in with the tension members on one side of the truss and the compression members on the other there would be a tendency for the two top chord angles to slip by one another as you would have a push up on one and a pull down on the other. For a long time we slotted the ends of the web members and slid them over the chords.

In order to bend the top chord we weld them together first. It

takes a weld about every 2 ft. along the toe and every 5 ft. along the back of the angles to hold them when being bent. In this way the chords are very tightly held together and we finally discontinued slotting the web members.

Technically there is an error in the design of these trusses as we build them in that the centers of gravity of the web members do not all intersect in a point on the center of gravity of the chord angles. Therefore you have unbalanced forces at the joints which you do not

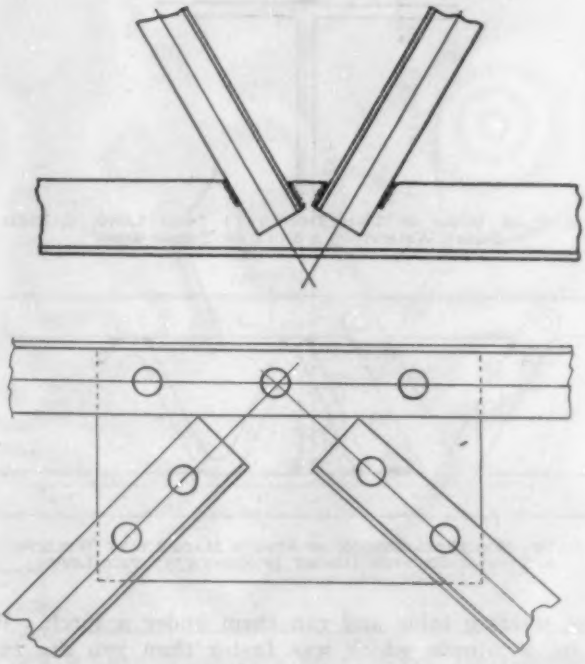


FIG. 8—ILLUSTRATING THE INTERSECTION OF THE GAGE LINES IN WELDED AND RIVETED CONSTRUCTION

have in a riveted truss where the gage lines all intersect in a point. I could never see much reason for worry on this question because: first, the web members in a curved chord truss theoretically have no stress; second, while the gage lines on a riveted truss intersect in a point the stress is carried through the rivets and does not by any means follow the gage line.

We make a complete line of welded trusses. Up to 40 ft. we make them in one piece. Between 40 and 65 ft. we make them in two identical halves; that is, you take two halves and turn one around and it fits on the first one.

In welding these trusses we place special clamps on the welding skids in the form of the finished truss. These clamps pull the top

chord into place if it has not been bent exactly. The web members are laid on the chords every other one being clamped beneath. These trusses will take a two ton load on the bottom chord at any panel point and make a very satisfactory truss for garages as they can hang their hoisting equipment from them.

We tried one lot of trusses with the chords made out of a T section made by splitting a 12 and 15 in. beam longitudinally through the center of the web. They were easy to split as we put the beams on

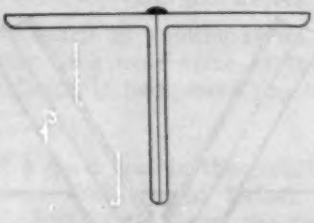


FIG. 9—A WELD OF THIS DESIGN (1 INCH LONG, $\frac{1}{4}$-INCH BEAD) WITHSTOOD A PULL OF THREE TONS

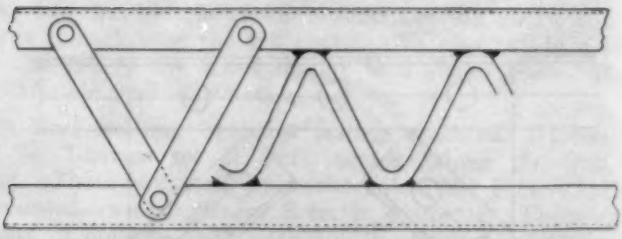


FIG. 10—SUGGESTED DESIGN OF STRUTS MADE UP BY WELDING. A TYPICAL RIVETED DESIGN IS SHOWN AT THE LEFT

the automatic welding table and ran them under a torch. We burned them at 42 in. a minute which was faster than you are supposed to be able to burn. At first we had trouble with the beams warping as we burned them. But we overcame this by leaving a foot at the end and after burning the rest coming back and burning this foot by hand.

This method of building trusses proved unsatisfactory due to the trouble in getting the top chord bent exactly. When they were off a little it was very hard to pull them over into place while the bent angles are easily pulled into place if they happen to be off a little.

Substation Work

About this time we considered welding electric substations. One argument against this was the galvanizing might weaken the welds. We took eight pieces and had half of them galvanized and the other four left ungalvanized. They were all made at the same time by the same welder. There was one ungalvanized piece that was stronger than the weakest galvanized one. Otherwise the galvanized pieces

held more, about 7 per cent on the average. At least galvanizing does not weaken welding.

We never welded up any substations, however, as we would have lost more trying to locate the details than would be saved.

Later the engineers raised the question whether in welding the heels of two angles together you would get enough penetration to give you a weld of any considerable strength. We welded two angles together

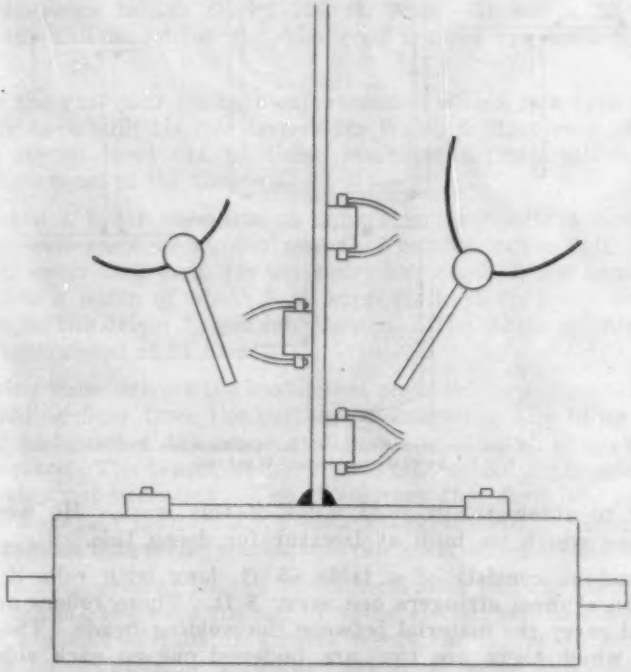


FIG. 11—SCHEMATIC DIAGRAM SHOWING THE ARRANGEMENT OF ROLLER GUIDES AND AUTOMATIC WELDING HEADS FOR SHOP FABRICATION OF GIRDERS, COLUMNS, LINTELS, ETC.

this way with a weld just 1 in. long and it took 6000 lb. to break it in tension.

We next tried building channel struts, using a bent rod in place of lacing bars. This would be feasible if you didn't use too big a rod. The bending has to be true in order to fit between the channel flanges and leave the backs straight and the right distance apart. We had a ¾ in. rod which was too heavy to bend by hand or any machine we had at that time.

When we got through we loaded up a riveted and a welded strut together. As they were in on the bolt-up floor we did not have enough head room to get a destructive load on them. The welded strut was a little bit stiffer than the riveted one. With a little experimenting

to cut down the size of the rods so that they would be bent in an air bender I believe this type of struts could be made welded.

Automatic Welding

Up to this time all of our welding had been done by hand. With automatic arc welding heads available Mr. G. A. Caldwell, vice-president and general superintendent of our company, thought there ought to

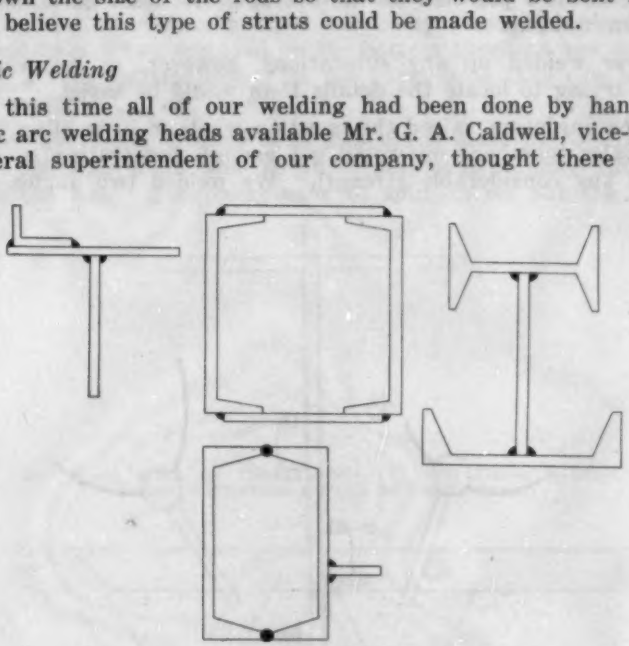


FIG. 12—SOME OF THE STRUCTURAL ASSEMBLIES PRODUCED BY AUTOMATIC ARC WELDING

be a way to automatically weld a lot of this work. He worked out the machine which we built at Decatur for doing this.

This machine consists of a table 65 ft. long with rolls 3 ft. long set between channel stringers one every 5 ft. These rollers are motor driven and carry the material between the welding heads. The welding heads, of which there are two, are fastened one on each side at the center of the machine. Just before the material gets to the welding heads it runs through several sets of guide rolls which line it up and hold it in place. Right over the center roll is a hold down roller that forces the two pieces together just before they reach the welding heads. The machine is controlled by a commutator on the drive shaft, which can be set to give welds of from 1 in. to 6 in. at spaces from 3 to 27 in. apart. The welding heads can be staggered, giving alternate welds first on one side and then the other. Either or both heads can be operated continuously or intermittently. This permits a continuous weld at the ends of girders or at the bottoms of columns. By throwing a switch you can switch to alternate welds. When the machine is welding the table travels at about 4¾ in. per minute. When the weld is completed the welding heads automatically shut off and the table travel speeds up to 40 ft. a min. After it has traveled to the place for the next weld the table slows down again and the arcs turn on.

We have run plate and beam lintels through this machine at very

little expense. The men take off a finished lintel with a hoist. Then place a plate and beam on the table and see that the machine has started at the proper place while the machine welds the lintel they take off the finished piece and get up the material for the next one.

The biggest single job put out on this machine was the girders and columns for the warehouse and shipping yard at our Chicago plant. The plant is located just north of Lake Street at Twenty-fifth Avenue in Melrose Park. We will be glad to show these to anyone interested.

The warehouse is 340 ft. by 135 ft. wide. It has a 20-ton crane running the full length of it. The roof trusses are welded 80 ft. in length.

During the past year we have experimented with a new type of welded work. We have built six pile drivers for Walsh & Masterson of Chicago. You can see at least one of these machines driving pile somewhere around town most of the time.

They have a lower base that is square and supports a circular rail. The upper base rests on a roller nest that rotates on the rail. The rear end of the upper base supports the boiler and engines, the front narrowing down to a width of about 3 ft. supports a 75 ft. tower at the end. This permits the driver to get into corners. The whole machine weighs in the neighborhood of 21 tons.

In making these drivers the beams that make the base were taken direct to the welding floor from the cutting department. The fit-up man laid them out and burned the copes and bevels on them. They were then tacked in place. The beams were continuously welded at all joints, which was probably not necessary. The H columns that form the leaders for the tower were laid horizontally. After being squared and leveled up the trussed framing that forms the back of the tower was built right on them.

We have done several jobs of stiffening beams and channels, by welding bars against the webs instead of using riveted stiffener angles. We have had a couple of jobs of girders where the stiffeners were welded at the top instead of being milled and fitted. It seems likely that the use of welding in this connection will steadily increase in the near future.

Printed information on the use of welding in structural work is considerably scattered. The following pamphlets have considerable information, especially about tests: "Arc Welding Structural Steel," published by General Electric Company. "Welding Progress in Structural Field," by Mr. W. Spraragen. Published by American Institute of Steel Construction. "The Arc Welding of Structural Steel," published by The Westinghouse Electric & Manufacturing Company.

Arc Welded Steel Deck Roofs—Welded Building

A. F. Davis†

LOYAL to the modern process of construction which they use so extensively, the Youngstown Welding Company of Youngstown, Ohio, has recently completed the construction of a crane mill type building, the framework of which is entirely arc welded, as well as the steel deck roof. This is one of the first applications of arc welding to steel roof

FIG. 1—SHOWING THE SIMPLICITY OF THE ARC WELDED CONNECTIONS AND THE PLATE GIRDERS

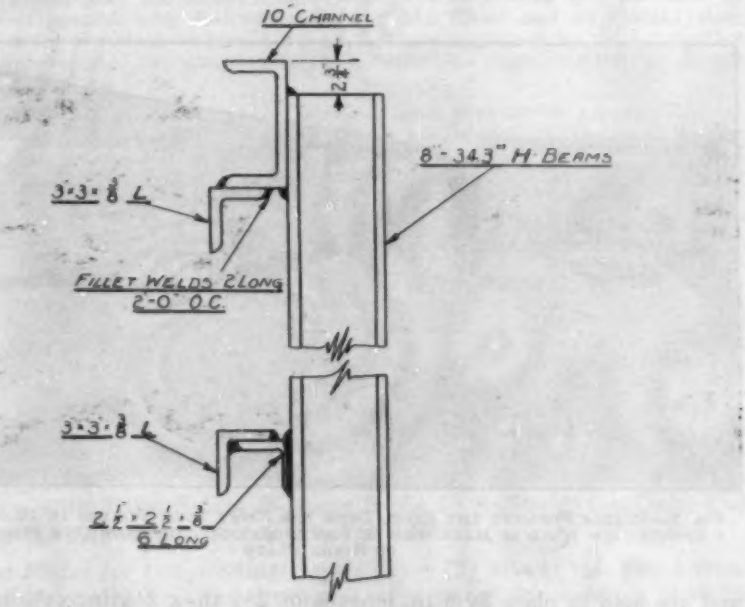
deck construction, however, the Youngstown Welding Company used this roof for some purposes for the first time in 1926.

The new building was designed and erected by the owners to provide additional working space. It is 140 ft. long, and is composed of a main bay, 80 ft. wide, and a side bay 20 ft. wide. It is so constructed that

†Vice-president, Lincoln Electric Company.

another side bay can be added with the least amount of trouble, any time in the future. The main bay houses an overhead traveling crane, which is also completely arc welded. C. R. Augden, Assistant Superintendent, was in charge of the erection of this structure.

The construction details are very simple, yet the building is extremely strong and rigid. The columns of the main bay are 8 in., 34.3 lb., H-beam, 23 ft. 6 in. high, and spaced at 20 ft. intervals through the length of the



DETAIL FOR SASH CONNECTION

Fig. 2

structure. The columns of the side bay are 8 in., 18.4 lb. I-beams. All angles and brackets necessary to support the various members were welded into place on the columns before they were raised, thus eliminating a great amount of welding in unhandy places.

The roof girders of the main bay were constructed of steel plate and fabricated in the shops of the owners of this new building. The web is ⅜ in. steel plate cut to size, and the flanges are made from ½ in. plate 8 in. wide. There are four stiffeners on each side of the web, made of ½ in. bar stock 2½ in. wide and arc welded in place. These girders rest on 9 in. pieces of 6 in. x 6 in. x ½ in. angle, welded to the face of the columns, as shown in Fig.1, and are then welded both to the column and to the angle. The roof girders of the side bay are 12 in., 36 lb., I-beams.

On the outside of the columns, at the top, a 10 in. channel is welded

longitudinally across the structure so that one flange of the channel is 2¾ in. higher than the top of the column. This channel serves as a support for the roof. A 3 in. x 3 in. x ⅜ in. angle is welded on the lower flange of the channel on the main columns to serve as a tie for the window sash. The lower tie for the sash is a similar angle welded into place on the main columns across the length of the building. The detail of this construction is shown in Fig. 2.

The spandrel members as shown in Fig. 1 are 8 in., 18.4 lb., I-beams

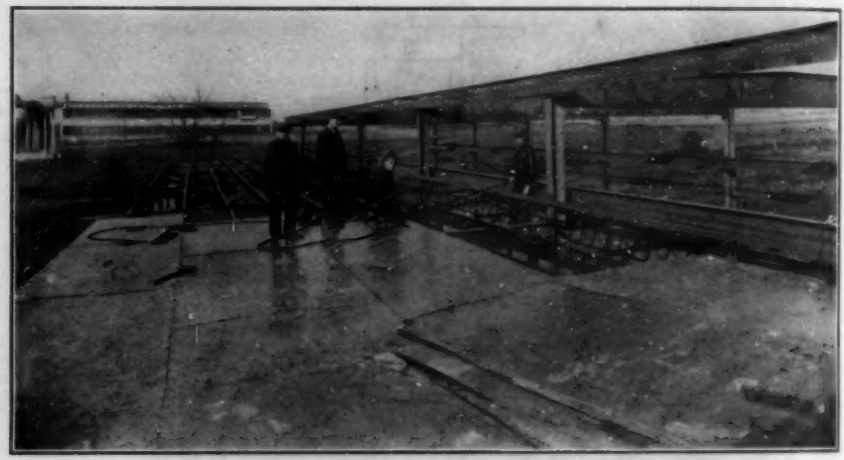


FIG. 3—PLATES FORMING THE STEEL DECK ARE FIRST TACK WELDED IN PLACE, THEN A CONTINUOUS WELD IS MADE ON ALL JOINTS MAKING THE ROOF ONE SINGLE PIECE OF STEEL PLATE

and are held in place by 9 in. lengths of 2½ in. x 2½ in. x ⅜ in. angles welded to the column, while being welded to the columns and to the angles.

The crane runway as shown in Fig. 1 is 15 in., 42.9 lb., I-beam, welded to the brackets as shown. A 40 lb. rail is welded to the top flange of these beams.

The roof of the building is fabricated of 12 gage steel plate, arc welded into place on bar joists running longitudinally through the building. Fig. 3 shows this construction. The plates overlap 1 in., the lower plate being tack welded to the joist, and the overlapping plate being welded solid to make it watertight. The pitch of the roof is obtained by the camber of the girder in the main bay, and by raising one end of the beam in the side bay.

One of the most interesting points in the construction of this building is that all work was done from simple working drawings. No tracings or blueprints were made. This is one of the advantages of arc welded construction, both in the structural and machine tool industries. Arc welded buildings are becoming more and more numerous and architects, engineers, and designers are rapidly turning to this process as a means of fabricating modern structures.

Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers

It is the policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later on in the proper place in the Code.

The Boiler Code Committee has received and considered suggestions for Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers. This movement is a result of the inadequacy of both riveted and forge welded construction for such drums or shells for boilers to operate at from 900 lb. to 1500 lb., unless the diameters are kept down to impracticable limits. On the other hand, recently, refinements in the application of fusion welding have made practical the welding of drums and shells of plate thicknesses up to 3 in. or more, and vessels constructed in this manner have been successfully used in large numbers in connection with petroleum refinery equipment. The proposed specifications which are now under the joint consideration of the American Welding Society and the Boiler Code Committee are submitted below for criticism and comment thereon from any one interested. Discussions of the proposed specifications should be mailed to the Secretary of the Boiler Code Committee, 29 West 39th Street, New York, N. Y., in order that they may be presented to the Committee for consideration.

1. Drums or shells of power boilers may be welded by the fusion welding process when materials suitable for welding are used in accordance with Pars. S-5 to S-17, or S-264 to S-279 of the Code, and providing the following requirements are fulfilled.

2. *Test Plates for Longitudinal Joints.* Two (2) sets of test plates from steel of the same heat as the drum plates, prepared for welding, shall be attached to the shell being welded as in Fig. 1, one set on each end of one longitudinal seam, so that the edges to be welded in the test plates are a continuation of and duplication of the corresponding edges of the longitudinal seam in the shell. Weld metal shall be deposited in the test plates continuously with the weld metal deposited in the longitudinal joint of the shell.

Note: Recommendations have been made that as an alternate the test specimen be allowed to be cut out of the welded longitudinal joint at any point, and the hole thus made welded up afterwards if the tests of the specimen show the vessel to be acceptable.

3. *Test Plates for Circumferential Joints.* When test plates are welded for the longitudinal joints, none need be furnished for the circumferential joints in the same vessel. Where a drum has circumferential joints and no longitudinal joint, a set of test plates of the same material as the shell shall be welded in the same way as the circumferential joint.
(Same as note under Par. 2.)

4. *Stress Relieving.* The complete welded structure or such welded parts separately as may be later assembled by means other than welding,

shall be heated uniformly to at least 1100 deg. Fahr. The structure shall be brought slowly up to the specified temperature and held at that temperature for a period of at least one hour per inch of thickness, and shall be allowed to cool slowly in a still atmosphere. The test plates shall be subjected to the above stress relieving operation either attached to or placed within the parent vessel.

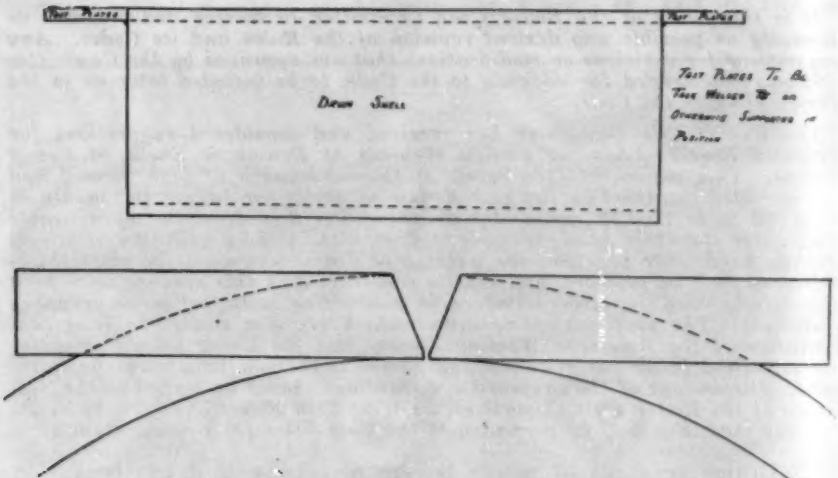


FIG. 1

SKETCH SHOWING TEST PLATES ATTACHED TO SHELL

5. *Test Specimens.* The inspector shall select one of the two welded test plates, from which the coupons for tension, impact, and bend tests, and for macro and micro examinations shall be removed as shown in Fig. 2.

6. *Tension Tests.* The tension specimen shall be transverse to the welded joint, and shall be the full thickness of the welded plate after the outer and inner surfaces of the weld have been machined to a plane surface flush with the plate. When the capacity of the available testing machine does not permit of testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements.

Each tension specimen should fail in the boiler plate, but if failure occurs in the weld metal or along the line of fusion between weld metal and the plate, then the tensile strength shall not be less than the minimum of the specified tensile range of the plate used.

7. *Bend Tests.* The bend test specimen shall be transverse to the welded joint of the full thickness of the plate and shall be of rectangular cross section with width 1½ times the thickness of the plate. When the

capacity of the available testing machine does not permit of testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements. The inside and outside surfaces of the weld shall be machined to a plane surface flush with the plate. The edges of this surface shall be rounded to a radius equal to 10 per cent of the thickness of the plate. The specimen shall then be bent cold under free bending conditions until the least elongation between any two points within and across the weld on the outside fibers of the bend test specimen is 30 per cent, with the width of any surface cracks deducted. No surface crack shall be longer than 10 per cent of the specimen's width, when the elongation of the outside fibers has reached 10 per cent.

8. *Impact Tests.* Three coupons for impact tests shall be taken

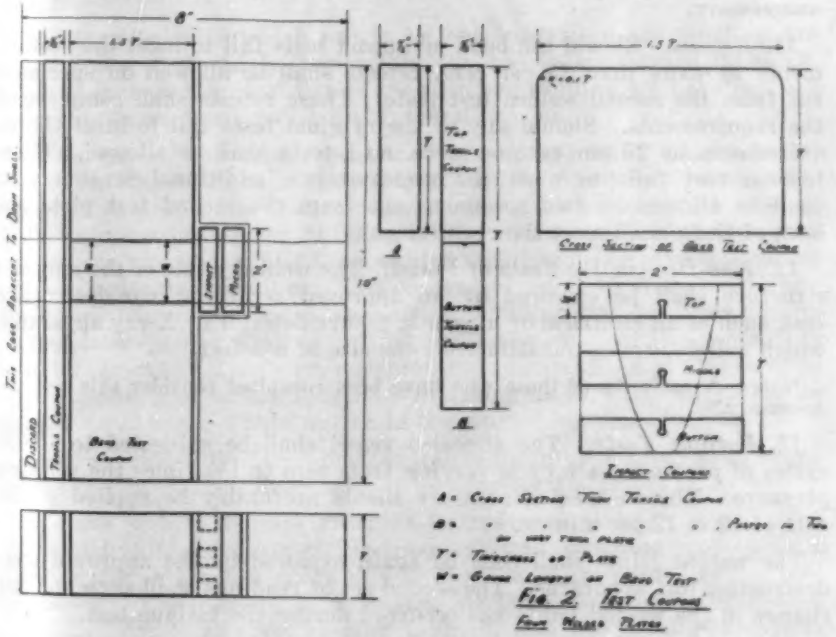


FIG. 2. TEST COUPONS

transverse to the welded joint and prepared so that the cross-section of the specimen through which fracture will occur shall contain: (1) the bottom surface, (2) the middle section, and (3) the top surface of the weld. The notch in the bottom specimen shall be opposite the bottom surface; and in the top specimen opposite the top surface. The minimum value of the impact test shall be 20 ft. lb. standard A. S. S. T. Charpy impact specimen.

9. *Chemical Analyses.* Drillings from the weld metal representing an average sample shall conform to the following requirements:

Manganese	.30-.60 per cent
Phosphorus	not over .04 per cent
Sulphur	not over .045 per cent
Nitrogen as iron nitride	not over .020 per cent

The nitride content shall be determined by the modified Allen method of the Bureau of Standards (Scientific Paper No. 457, U. S. Bureau of Standards).

Note: A majority of those who have been consulted consider this test unnecessary.

10. *Macro and Micro Examinations Tests.* Macrographs prepared from coupons taken across the welded joints and etched with suitable reagents shall show no laps, excessive porosity and incomplete fusion. Micrographs of polished specimens taken in the same manner shall show no evidence of coarse-grained material.

Note: A majority of those who have been consulted consider this test unnecessary.

11. *Retests.* Should the bend or impact tests fail to meet the requirements by more than 25 per cent, retests shall be allowed on specimens cut from the second welded test plate. These retests shall comply with the requirements. Should any of the original tests fail to meet the requirements by 25 per cent or more, no retests shall be allowed. If the tension test fails to meet the requirements, additional tension tests shall be allowed on two specimens cut from the second test plate and both of these shall meet the requirement.

12. *Non-Destructive Tests of Vessel.* The welded joints of the annealed structure shall be explored by an approved recording non-destructive test, such as an electrical or magnetic fissure detector or X-ray apparatus, which will determine quantitatively the size of a defect.

Note: A majority of those who have been consulted consider this test unnecessary.

13. *Fatigue Tests.* The annealed vessel shall be subjected to 10,000 cycles of pressure, each cycle varying from zero to 1½ times the working pressure. These cycles of pressure should preferably be applied at the rate of 10 to 12 per minute.

The welded joints shall then be again explored by the approved non-destructive test apparatus. The second set of readings shall show that no change in the welded joints has occurred during the fatigue test.

Note: Objections have been raised against this test by those who consider it unnecessary or capable of dangerously affecting the structure.

14. *Holes.* No holes shall be located in a welded joint.

When holes in the plate are located near a welded joint, the minimum distance between the edge of a hole and the edge of a joint shall be equal to the thickness of the plate, when the plate thickness is from 1 in. to 2 in. With plates less than 1 in. thick, this minimum distance shall be 1 in. With plates over 2 in. in thickness, the minimum distance shall be 2 in.

15. *Allowable Working Stress.* When constructed under the above

provisions, the maximum unit working stress of a welded joint may be taken as one-fifth of 80 per cent of the minimum of the specified tensile range (16 per cent) of the plate used.

Note: Criticisms have been received which claim that the maximum unit working stress allowed should be from 90 to 100 per cent of the minimum of the specified tensile range.

Arc Welding of Structural Steel*

J. J WALLACE†

THE American Welding Society has been well known for many years. The result of its efforts and activities have been felt in almost every American industry. The building code which you have developed is a classic, and no doubt will bring greater results as the years roll by.

The many benefits which are to be obtained from arc welding are so numerous it would be impossible for one to enumerate them all. In our short experience of two years with arc welding we have learned a few things we trust will be of interest to you.

We are one of the smaller shops who have gradually sought to expand our business through arc welding; and we are keeping two motor generator sets and one transformer set busy. We started in first of all to weld up lintels for building work. On one job a change was made where two angles had been welded together using pipe separators as the interlocking medium. The contractor on the job took a strong laborer with a heavy maul and after pounding for an hour finally 'phoned us to send out some cutting equipment so that the separators could be removed. This gave considerable confidence in arc welding to our customer; and before long he was asking us to weld everything so that the rivet heads would not be in the way of his construction.

The first job we did for ourselves was to make up a small shop crane using short lengths of material. It was most satisfactory.

We have welded trusses from 18-ft. span up to 96-ft. span. The last named unit was a bow string truss and was composed of 2—6 x 4 x ⅜-in. angles in the top chord and 2—5 x 3 x ⅜-in. angles in the bottom chord. The vertical compression members were made of 2—3½ x 3½ x ¼-in. angles set in star fashion, and the tension members were composed of 1—3½ x 3½ x ¼-in. angle. Upon an analysis of the stresses you will find that some of the shorter compression members are not stressed as high as they could be, and also there is some extra material in some of the tension members. However, the unwieldiness of the finished product and the erection stresses prompted us to use a little more steel in some spots than appeared necesary. We used no gusset plates with the following exceptions: the center connection has a gusset plate; the end bearing has a gusset plate and the top chord has a gusset plate at the quarter point. The center con-

*Paper presented at Nov. 7 meeting of Chicago Section, A.W.S.

†Manager, Joliet Engineering Company, Joliet, Ill.

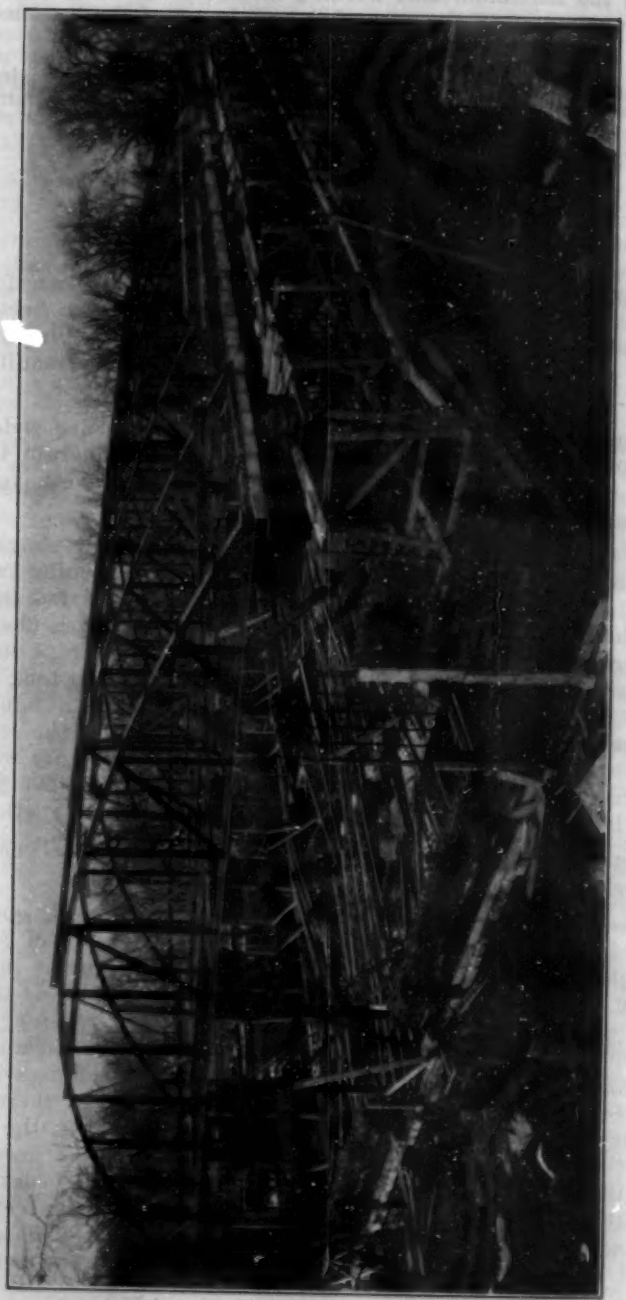


FIG. 1—FACTORY BUILDING WITH 96 FT. SPAN, ALL WELDED TRUSSES

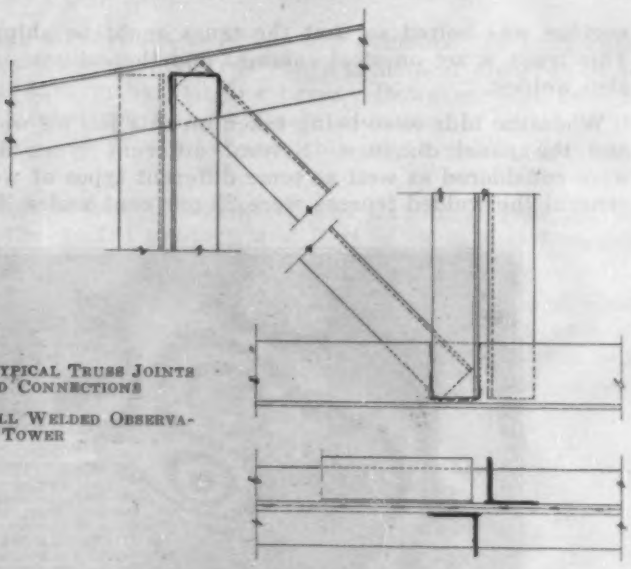


FIG. 2 (RIGHT)—TYPICAL TRUSS JOINTS WITH WELDED CONNECTIONS

FIG. 3 (BELOW) ALL WELDED OBSERVATION TOWER

nection was bolted so that the truss could be shipped in two units. This truss is set on steel columns and the column caps and bases are also welded.

When the bids were being taken on this job we were given the span and the panel distance. Several different types of riveted trusses were considered as well as some different types of welded trusses. In general the welded trusses were 25 per cent under the riveted trusses

FIG. 4—PORCH RAIL ALL WELDED

in price. The saving, of course, is made up in several different ways. In the first place, a welded truss takes less material than a riveted truss; the drawings are much simpler; the laying out and template work is reduced to a minimum; and welding is certainly considerably less labor than punching and riveting. The total saving is a large factor in the final cost.

Normally, we do not try to sell a welded article as a cheaper article. We tell our customers about the advantages of arc welding. In other words, a welded job will do more work for the same amount of money.

We have welded connections to beams and columns. In some cases the columns are 40 to 50 ft. high. We have girders of about 40 to 50-ft. span, and we have many machine bases. However, just now we are doing some riveted work, the ultimate consumer of which is the Soviet Government. We tried to change this job to welding but were not successul.

Many high grade architects, engineers and structural men are not ready to accept the welded product, and it is to them that I request consideration for the new fabrication.

We have one job of approximately 200 tons, a combination of riveting and welding. During the planning period our engineers were invited to make an estimate of the steel work; the concrete people were invited to make a preliminary study of the cost of using concrete

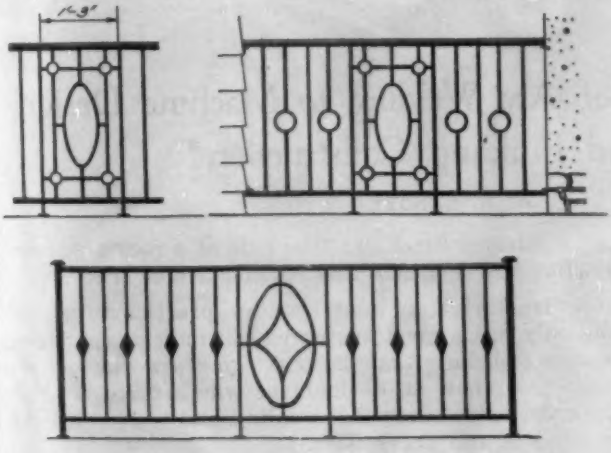


FIG. 5—STOCK PORCH RAILS

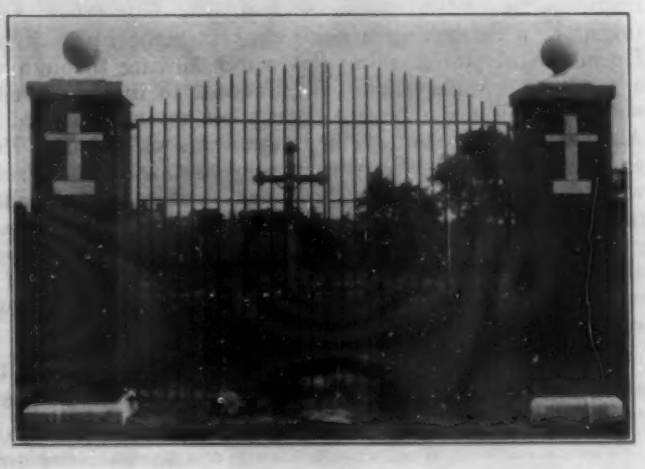


FIG. 6—ALL WELDED CEMETERY GATE

columns and girders. The total expense of the building was about $150,000. It was the contention of the owner, architect and contractor that by the use of structural steel a saving of $20,000 could be made. Steel joists, steel girders and steel columns reduced the dead load and are responsible for this saving.

We have an all-welded observation tower. The purchasers became enthused over arc welding. In order to satisfy them we were obliged to remove the erection bolts, instead of the customary welding of the bolt threads to prevent the nuts from turning. This tower is 24 ft. square at the base; 20 ft. square at the top platform and is 30 ft. high at the observation floor. The rails, steps, in fact everything is welded. The only bolts are the foundation bolts.

If we knew of a process of welding the shoes to the concrete we would have been very glad to weld them.

Application of Arc Welding to Machine Design and Building Construction*

A. M. CANDY†

"THIS Is the Age of Riveted Steel" was the title of a recently shown moving picture. But how long will this statement hold true?

While the transition from riveting and foundry practice to welded construction even now only has a good beginning, all indications during the past two years lead us to believe that the next five years will see very extensive innovations. Even now it is doubtful whether the average reader actually realizes the extent to which welding and welded articles enter into our every-day life and necessities.

To illustrate how true this latter statement is let us follow the daily routine of a modern business executive. Our friend arises in the morning after a refreshing night's sleep at home in an all welded metal bed. He makes his toilet using hot water flowing through welded pipe from a welded hot water tank. He proceeds to the breakfast room where his wife serves him with coffee from a pot having a welded handle and spout. Also waffles made in a welded aluminum waffle iron. He steps out to his garage and enters his automobile containing hundreds of welds and welded parts such as body, gas tank, muffler, radius rods, rear axle housing, valves, tappets, universal joints, propeller shaft, etc. He looks at his gasoline gauge and notices the gas is low so his first stop on his way to the office is at his favorite filler station where he is served with gas from a welded pump drawing the fluid from a buried leak proof welded steel storage tank.

Our friend then proceeds on his way passing several tank shops where welded tanks are made and industrial plants where arc welded struc-

*Paper presented at Feb. 10 meeting of Western New York Section, A. W. S.
†Welding engineer, Westinghouse Electric and Manufacturing Company.

tures are used instead of castings. He finally arrives at the terminal of the elevated railroad where he parks his car for the day in an arc welded garage. He boards the elevated car which has welded body parts, wheel flanges, brake rigging, truck parts, motor frames, etc., and gets its power from a 1000 kv-a. turbo generator constructed entirely of arc welded steel.

Our friend finally arrives at his office building the frame of which is of arc welded steel. He rides up the welded elevator shaft on an elevator

FIG. 1—MODERN WELDED END BELL WITH ITS RIVETED PREDECESSOR ON THE RIGHT

deriving its power from an all arc welded elevator motor generator. He enters his office and hangs his hat and coat on a welded hat tree, sits down to his welded metal desk, on a welded swivel chair.

Shortly this gentleman receives a telegram requiring his presence in Hot Springs, Va., that afternoon, so he proceeds to the railroad station and enters a coach having many welded parts and rides behind a locomotive with welded frame, welded fire-box and flues. The train passes over an all arc welded bridge, also rail joint welded together, and finally arrives at the flying field where he enters an airplane having an all welded fusilage, engine water jacket, spark plugs, etc.

After a few hours of flying he arrives at Hot Springs, Va., where he stops at the arc welded Homestead Hotel where he has an important

business conference. That night he retires in another all welded bed and so completes his daily cycle of use of welded products.

Now all of this does not exist by chance but is the result of systematic and economical development produced by engineers who are always alert to accept and adopt modern means of producing a superior product. Neither do such developments take place over night. They are the result of consistent study to determine wherein past products and methods can be changed, modified or discarded wholly or in part to fully capitalize

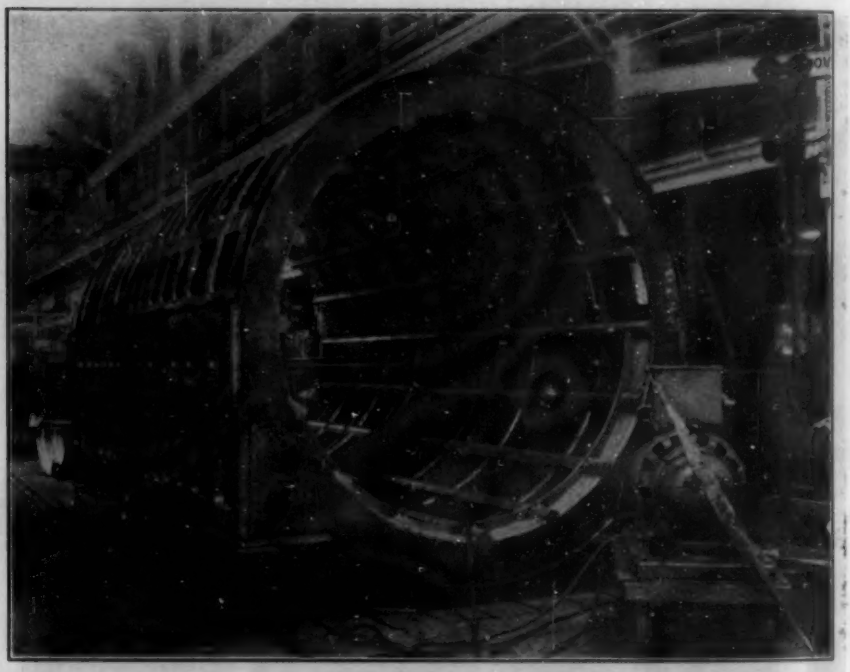


FIG. 2—FRAME FOR A 100,000 KV-A. ELECTRIC TURBINE GENERATOR CONSTRUCTED ENTIRELY OF ARC WELDED STEEL PLATE BARS AND SHAPES

the most economical structure that can be produced by that young industrial giant—The Welder.

That designer who is to make the outstanding success must clear his mind of prejudices to previous designing methods. He must not simply consider using welding to replace rivets in a riveted structure nor attempt to exactly duplicate a cast machine with duplicate sections tied together with weld metal.

To illustrate how some of our modern designing engineers have looked at their problems with an open mind we will cite a few examples. In Fig. 1 we have a modern welded end bell on the left and a riveted predecessor on the right. The riveted specimen has angle stiffeners on the outside and a corner binding angle on the inside. In the welded design the inside angle is entirely eliminated and the outside stiffeners are

simply bar or strap steel on edge. Now all the riveted structure could have been welded but much more welding would be required, unnecessary steel in angles would be used, the total weight would be about the same and the cost would not have been reduced to the same degree.

In Fig. 2 we see a skeleton frame for a 100,000 kv-a. electric turbo generator constructed entirely of arc welded steel plate bars and shapes. Each section is selected on the basis of the strength required. Nothing need be sacrificed by the demands of the pattern maker or the foundry man. Many sections of a casting are determined by the flow of metal in the mold, the ability of the molder to get the pattern

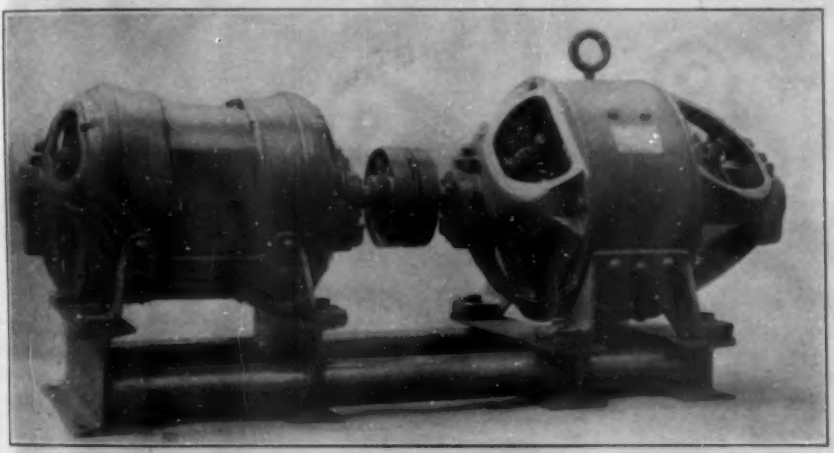


FIG. 3—NEW DESIGNS OF WELDED BEDPLATES SIMILAR TO THE ONE SHOWN GIVE MAXIMUM STRENGTH WITH MINIMUM WEIGHT

out of the mold, the core-making requirements, etc. In the case of the casting of this type of machine the only reasonable way to attach the laminations in the frame is to provide dovetails on the laminations which fit into dovetail slots machined in the ribs inside of the cast iron frame. Therefore, expensive machining operations of boring and slotting the frame ribs are required. In the welded design the only machining required on the frame is to drill a few holes for bolts. These bolts are carefully spaced next to the ribs and welded to them at intervals of about 10 in. The laminations are then stacked on these bolts. As a result of this modern open minded design we have a much better structure saving about 4 per cent in weight and an appreciable amount of machining labor. If all details of the cast structure had been duplicated no saving in weight or machining would have resulted. In fact, the machining expense would be greater because on the whole cast iron is somewhat easier to machine.

Fig. 3 represents probably one of the most radical departures in substituting an entirely different welded structure to provide a base or bedplate for two connected machines. The first welded bedplates were reasonably close in constuction and appearance to the familiar

cast iron bedplate. These designs showed practically no saving in weight or labor. By considering the problem fundamentally, however, it was evident that four lines of support were required for the feet of the machines. Standard beams of practically the correct height could be chosen. The problem then became one of selecting the most economical shapes to tie these four members together into a light rigid bedplate. This was effectively accomplished by using extra heavy pipe passing through circular holes burned through the webs

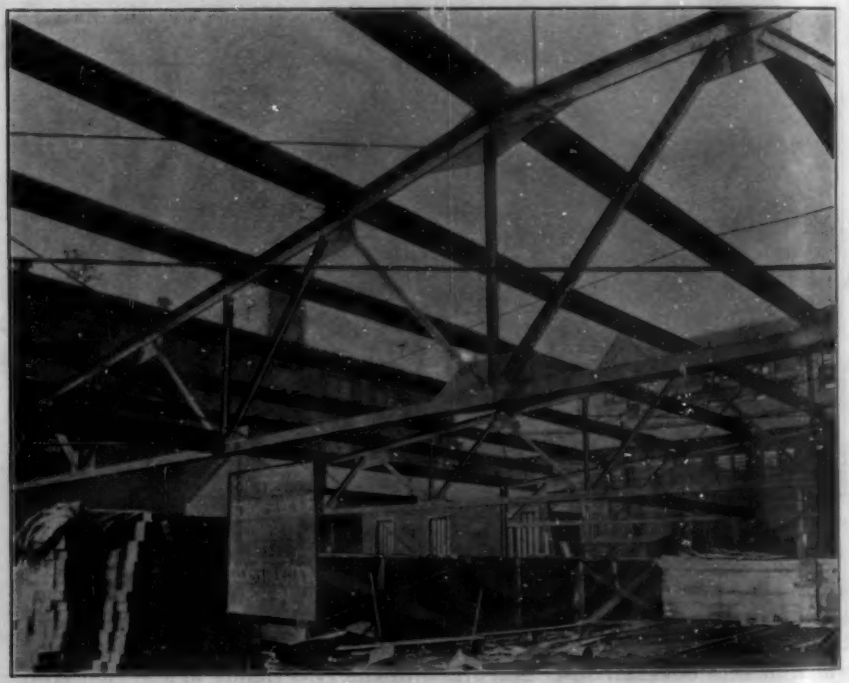


FIG. 4—WELDING IS EMPLOYED TO BUILD THIS ROOF TRUSS, USING ALL GUSSET PLATES

of the two inner members and butting against the webs of the two outside members. This design gives a bedplate of maximum strength for a minimum of weight and reduces the labor to a minimum.

Examples of modern design of this type could be multiplied, but we believe these are sufficient to impress the machine designer of the necessity of fundamental thinking if the maximum benefits are to be derived by the use of welding.

Similar constructive thinking must be employed in building or bridge design if the welded structures are to produce the maximum benefits. For example, in bridge design work it is not at all unusual to find the detail connecting material such as gussets, angles, etc., amounting to 30 per cent or 35 per cent of the total weight of the bridge, whereas

a rationally designed welded structure will have no more than 3 per cent to 5 per cent of its total weight in detail connecting material.

Fig. 4 is given as typical example of simply substituting welding for riveting to produce a roof truss using all gussets. Now, if the truss has been designed for welding the gussets could have been entirely eliminated by making the web members long enough to tie directly to the bottom cord and rafter members. As it stands the web members must be welded to the gussets and then the same amount of weld-

FIG. 5—THIS ROOF TRUSS IS WELDED WITHOUT USING GUSSETS, EXCEPT ON THE EXTREME ENDS OF EACH TRUSS

ing must be repeated to tie the gussets to the main members so we not only waste material in the gussets but also double our welding labor. To fully appreciate these points one must look at a rationally designed truss, as shown by Fig. 5, where no gussets are used except at the extreme ends of each truss. All members of these trusses are T shapes, which also simplifies the design and welding work.

That welding has come to stay and will make rapid advancement during the next few years in building—bridge and machinery construction may be evidenced by the fact that the Westinghouse Electric and Manufacturing Company now has completed and under construction over 2000 tons in 15 buildings and railroad bridges and is using over 1000 tons per month of steel plate, bars and shapes in building electrical apparatus of various types. Castings for machinery are rapidly

becoming obsolete except for small complicated parts or small simple parts of very large production.

Advantage of Arc Welding

All of this work and development has taken place due to the proven advantages and sheer merit of arc welded construction. In the field of buildings, bridges and similar structures the principal advantages are:

1. The weight of the material in fabricated beams and girders can be reduced 18 per cent to 25 per cent by designing for arc welding instead of riveting

2. No material need be removed from columns or tension members such as rivet holes, and therefore, in many cases smaller members can be used for welded construction.

3. The weight of material for connections can be reduced by 50 per cent to as high as 90 per cent in some cases as compared with the requirements of riveted construction.

4. Absolute fixation of one member to another can be readily obtained.

5. Continuity of lines or beams or girders can be readily obtained permitting the use of smaller members in many cases.

6. Much greater rigidity can be produced in a properly designed welded structure.

7. Overlapping members can usually be completely sealed by weld metal, thereby excluding moisture and preventing corrosion between the "Faying" surfaces.

8. A welded structure is much easier to paint than a riveted structure.

9. Changes in or additions to structures can be made in the field with great saving in both time and expense.

10. In many cases simplified and more pleasing designs are possible with welded construction.

11. Roof trusses can be constructed with much greater symmetry, thereby reducing secondary stresses.

12. The welding process is practically noiseless, which is an asset for both shop fabrication and particularly field erection work.

In the field of machinery design and construction the advantages of using arc welded shapes, plate and bar stock to produce a substitute for similar cast iron structures are even more outstanding, due to the inherent advantages of commercial rolled steel over cast iron and the advantages of the fabrication process over present-day foundry and pattern shop practices.

The average ultimate tensile strength in pounds per square inch of the materials are:

Cast Iron.....	22,000 lb.
Rolled Steel.....	55,000 lb.

The modulus of elasticity of the two materials are:

Cast Iron	12,000,000
Rolled Steel	30,000,000

In addition to these outstanding physical advantages of rolled steel we find that pattern making and foundry practice often handicap the designer by requiring sections in castings much heavier than demanded by strength consideration. Due to these and other factors we find the following advantages occurring to arc welded machinery.

1. Weights in many cases have been reduced as much as 50 per cent.

2. Simplified details of design have been made available by welded construction.

3. Homogeneity of metal is much more definite in rolled steel than in castings.

4. Delivery dates have been materially reduced due to elimination of pattern and core making.

5. Pattern storage charges are eliminated.

6. Casting scrapping due to sand or blow holes is eliminated.

7. Repairs to welded machines are much less likely to be required and when required are much more dependable and less expensive.

8. Capital investment to produce welded machines is only 5 per cent to 8 per cent of that required for cast construction.

Discussion Paper of "Material Transference in the Welding Arc"*

A. W. SLOCUM†

I do not believe that much metal is being transferred in pictures 3, 4, 5 and 6, appearing in the December, 1929, issue of Journal of the A. W. S. In these pictures the metal joining electrode to plate is in a continuous column. Pictures 7, 8, 9 and 10 are specially instructive. Of special importance are the alternations of well-rounded forms with contraction into serrated contours with occasional sharp tips. Inferences: The metal in the mushroom tip is not continuous but probably spongy like a loaf of bread. The holes are filled with vapor of some component or with gas of some kind. I have no doubt that it is vapor of some component of the electrode with slightly lower boiling point than the rest of the electrode. In picture 7 the arc has just ceased from that portion of the metal near the number 7, evidence of this is

*Paper published in the December, 1929, issue, Journal of the A.W.S.
†University of Vermont.

the beginning of the formation of the angular contour. In picture 8, the contour becomes serrated; here the vapor inside has partially condensed. In figure 9, the arc has begun to play again and the metal boils, and the increasing quantity of vapor blows out the mass like blowing a bubble with rounded contour. (Gases absorbed and liberated might act in the same way, but I believe that they be altogether much too slow to account for the phenomenon.) Note that while the southwest position of the spongy mass is expanding, the northeast is cooling and contracting, as indicated by the concave form of surface and the movement of the pointed tip.

In fig. 10, the spongy globule has expanded till it touched the plate, then suddenly cooled, the vapor collapses and the shell and some of the metal within the spongy mass adheres to the plate. One guess is as good as another as to what is happening above the isthmus. I guess it is collapsing into a continuous liquid column like picture 6.

These pictures are shadow pictures of the metal of the arc. The arc itself is not seen. The electron stream with its accompanying vapor that constitutes the arc flies about probably too rapidly to be caught by this camera. It is also surrounded by a luminous cloud which increases the difficulty of photographing it. The alternating heating and cooling shown in figs. 7, 8 and 9 is, I believe, caused by the wandering of the electron stream of the core of the arc. The negative end of the core is prone to search for spots of oxides, especially calcium oxide, and the heating is somewhat localized to such spots.

CURRENT WELDING LITERATURE

A Portable Gas Oven. P. Gibbons. Mech. World (Manchester) (Dec. 27, 1929), Vol. 86, pp. 603-604. Design and construction of portable oven which may be used as preheating table or welding bench; preheating muffles.

A Study of the Flange Pipe Joints. L. T. Jones. The Welding Engineer (December, 1929), Vol. 15, No. 2, pp. 57-60. The flange type of weld is easily made "in position" in the field and provides partial relief from stresses created by seasoned heat and cold.

Aircraft Welding, Including the Development of an Efficient Welding Department. R. F. Hardy. West. Machy. World (December, 1929), Vol. 20, pp. 441-442. Factors discussed are personnel, favorable working conditions, efficient equipment, first class material.

Allentown Viaduct Repaired by Welding and Guniting. E. W. Meckley. Engineering News-Record (Feb. 13, 1930), Vol. 104, No. 7, pp. 289-290. Tilghman Street Bridge can now carry modern highway traffic safely. Savings in time bridge was out of service and in cost over a new structure.

Application of Welding Processes on the Boston and Maine. M. A. Thompson. Welding (February, 1930), Vol. 1, No. 4, pp. 225-228. Thousands of dollars saved each year through the use of an automatic shape cutting machine.

Applications of Welding to Construction of Electrical Equipment. Soudeur-Coupeur (Liege) (October, 1929), Vol. 8. pp. 110-112. Applications of welding in manufacture of various electric machines such as transformers and mercury-vapor rectifiers are discussed.

Applications of Welding to Construction of Electric Equipment. J. W. Meadowcroft. Metal Stampings (November, 1929), Vol. 2, pp. 895-899. Early methods of constructing automobile bodies; welding of stamped parts; tests of various types of welds.

Arc Welding in Manufacture of Electric Machinery. C. Ritz. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1740-1741.

Arc Welding Problems Less Formidable. Elec. World (Feb. 8, 1930), Vol. 95, No. 6, pp. 297-298.

Automatic Arc Welding Machine. V.D.I. Zeit. (Berlin) Supplement (Dec. 7, 1929), Vol. 73, p. 78. Particulars of machines made by A.E.G. for welding of tanks, pipe, shafts, etc.

Belfinish Electrodes for Marine Construction and Repair Work. Welding Journal (London) (October, 1929), Vol. 26, p. 314. Results of tests made with Belfinish electrodes which have been submitted and approved by Lloyds for use on ships.

Code Revisions for Pressure Vessels. The Welding Engineer (February, 1930), Vol. 15, No. 7, pp. 37-40. Air vessels of greater sizes and pressures may be welded if proposed revisions to A.S.M.E. Code are adopted.

Copper and High Copper Alloy Welding. I. T. Hook. Brass World (October, 1929), Vol. 25, pp. 242-243.

Copper Welding. R. Samesreuther. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1731-1732. Discussion deals principally with copper welding of locomotive fireboxes; comparison of riveted and welded copper fireboxes; method of welding and after-treatment of welds.

Design and Erection Supervision of Oxwelded Piping. D. S. Lloyd. Canad. Machy. (Toronto) (Nov. 28, 1929), Vol. 40, pp. 76-80. Procedure control in gas welding pipe joints is discussed; design and layout of joints; selection and inspection of material; check of welder's ability; preparation for welding; welding technique; inspection and test. Paper presented before American Society Heating and Ventilating Engineers.

Design of Resistance Welding Machines. W. E. Smith. The Welding Engineer (February, 1930), Vol. 15, No. 2, pp. 55-56. Strength of parts, method of applying pressure elimination of magnetic losses, insulation, are some of the factors to be considered.

Destructive and Non-Destructive Tests. J. R. Dawson and A. B. Kinzel. Acetylene Journal (February, 1930), Vol. 31, No. 8, pp. 325-331. A critical discussion of testing welds and the significance of results. Several new methods of testing are available together with modifications of old methods from which essential information can be derived, but which must be carefully interpreted.

Economy of Material in Welded Construction. M. Hilpert. Welding Journal (London) (October, 1929), Vol. 26, pp. 315-316 and 331. Figures and data give probable reduction in weight secured by welding process, compared with other methods of assembly. Abstract of paper presented before Matls. Congress in Berlin.

Efficiency of Welded Joint. Amer. Mach. (Dec. 26, 1929), Vol. 71, p 1055. Efficiencies of some of principal welded joints are shown with explanatory notes. Condensed from technical report by H. M. Longridge, Managing Engineer, British Engine Boiler and Electrical Ins. Co.

Electric Arc Welding. A. Ramsy Moon. Mechanical and Welding Engineer (Jan. 20, 1930), Vol. 4, No. 1, pp. 5-11.

Electric Butt Welding (Fusion Process). T. Wuppermann. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1758-1763. Application to shipbuilding of electric butt welding according to method described has been tested and gives satisfactory results.

Electric Spot Welding and Its Use. A. M. Searles. Sheet Metal Worker (Dec. 27, 1929).

Electric Welding by the Carbon Arc. J. C. Lincoln. Journal of the A.I.E.E. (February, 1930), Vol. XLIX, No. 2, pp. 110-113.

Electrical Resistance Flash Welding. M. L. Eckman. Welding (February, 1930), Vol. 1, No. 4, pp. 236-240. The author has clearly set forth the fundamental principles of the process, how and where these machines can be used and the advantages gained by their usage.

Electrically Welded Ships. The Welder (January, 1930), Vol. 1, No. 3, pp. 3-6.

Electrically Welded Steel Structures. E. Rosenberg. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1743-1746. Preliminary tests are described for welding of steel railroad bridge, based on which basic calculations are recommended;

suggestions for simplification of design with regard to advantages of electric welding; reliability of welded joints; description of electrically welded roof of 100 m. long and 12 m. wide pavilion.

Electrodes for Electric Resistance Welding. F. E. Elge. Welding Journal (London) (November, 1929), Vol. 26, pp. 354-356.

Elusive Markets Lead Steelmakers in Merry Chase. G. H. Manlove and W. H. Lloyd. Iron Trade Review (Jan. 2, 1930), Vol. 86, No. 1, pp. 7-10.

Examining Arc Welds for Quality. G. C. Ward. The Iron Age (Jan. 30, 1930), Vol. 125, No. 5, pp. 369-370. Kerosene penetration indicates soundness only. Quality of tone cannot distinguish good from fair welds, nor can visual inspection. Correct procedure control is indispensable.

Extend Applications of Both Welding and Riveting. Iron Trade Review (Jan. 2, 1930), Vol. 86, pp. 26-27.

Fabricated Fittings—Their Use in Pipe Welding. R. E. Fritsch. Heat. and Vent. (January, 1930), Vol. 27, pp. 91-92. Discussion of necessity of fabricated pipe fittings for pipe welding; designer able to calculate with high degree of exactness, not only angles of pipe layout, but also actual spacing; brief consideration of pipe welding developments; consideration of pipe welding for heating systems. Abstract of paper read before Int. Acetlyene Assn. in Chicago.

First All Arc-Welded Gantry Cranes. L. S. Barry. Welding (February, 1930), Vol. 1, No. 4, pp. 255-57.

Fusion Welding of Unfired Pressure Vessels, The. L. W. Schuster. The Welding Jaurnal (January, 1930), Vol. 27, No. 316, pp. 6-16.

Gas Welding Chrome-Nickel Steel. H. S. Lansing. The Welding Engineer (February, 1930), Vol. 15, No. 2, p. 53. High strength can be obtained in this material by making proper allowance for the peculiar characteristics of the metal.

How Are "A.W.P." Electrodes Made? The Welder (January, 1930), Vol. 1, No. 3, pp. 7-12.

How to Weld Duralumin. Aero Digest (December, 1929), Vol. 15, p. 164. Precautions to be observed in preparing and welding duralumin are discussed; properties of duralumin; sheet duralumin should be spaced ¼ in. per ft. of seam; tensile strength which can be expected of welds made in duralumin varies with methods used in heat treating and quenching.

How Welding Assists the Maintenance Engineer. C. Sylvester. Elecn. (London) (Jan. 10, 1930). Vibration breakdown; value of welding plant; some instances of effective use of welding, i. e., armature shafts of 500-b.hp. motor installed for starting large Diesel engines and loose shaft collars.

Impressions of American Industries, Including Welding. E. A. Atkins. Welding Journal (London) (November, 1929). Discussion. Vol. 26, pp. 349-354.

In the Hydro-Electric Industry. F. J. Fitzgerald. Universal Eng. (January, 1930), Vol. 51, pp. 22-25.

La Soudure Electrique a L'Arc et Ses Applications, by M. Maurice Lebrun. Covers Chapter 1. Analogy of Electric and Hydraulic Phenomena. Chapter 2. Electric Arc Welding and Cutting. Chapter 3. Examination and Testing of Welds. Chapter 4. The Electrodes—Their Characteristics. Chapter 5. Welding Equipment. Chapter 6. Applications of Electric Arc Welding.

Magnetic Testing of Welds. The Welding Engineer (February, 1930), Vol. 15, No. 2, pp. 31-35. Description of a method of obtaining images of weld structures by means of filings in a magnetic field and interpretation of the results.

Metallic Electrodes for Cast Iron Arc Welding. S. Satch. American Institute Min. & Min. Engrs. Trans., 1929, pp. 144-165, including discussion. Writer has been able to obtain series of cast irons, from gray to white, without using cast-iron electrodes, but by coating on wrought-iron bars mixtures of carborundum and graphite; practical application of cast-iron welding.

Oxy-Acetylene Tips (February, 1930), Vol. 8, No. 7. Tight Joints in Commercial Copper. For Vitreous Enameling. Furnace for Bending Pipe. Two Hours to Spare. To Insure Perfect Combustion. Aircraft Maintenance. Training Course for Aircraft Welders.

Oxy-Acetylene Welding Process, The. F. J. Fitzgerald. Sheet Metal Worker (Dec. 27, 1929), Vol. 20, pp. 823-825.

Practical Applications of Bronze Welding. Macy. (London) (Nov. 7, 1929), Vol. 35, p 167.

Practical Side of Structural Welding. A. L. Wilson. The Welding Engineer (February, 1930), Vol. 15, No. 2, pp. 47-52. How one steel fabricating shop successfully met the problems introduced by the adoption of welding for jointing rolled shapes.

Procedure Control. Welding Journal (London) (October, 1929), Vol. 26, pp. 328-330.

Progress in Pipe Line Transportation. W. G. Heltzel. Pipe Line News (February, 1930), Vol. 2, No. 3, pp. 14-19.

Progress in Use of High-Grade Welding Rods. F. Sommer. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1764-1768. After description of welding rods in general use, some new types are described; special mention is also made of new rods for corrosion and heat-resisting welds and wires for autogenous welding.

Proper Control in Welding Pressure Vessels. Heat. Piping and Air Conditioning (January, 1930), Vol. 2, p. 11.

Proposed Welding Procedure for Pressure Vessels. Boiler Maker (January, 1930), Vol. 30, pp. 11-14.

Reclaiming Steel Sharpener Dies by Oxy-Acetylene Welding. M. M. Thomason. Canad. Min. Jnl. (Gardenvale, Que.) (Dec. 20, 1929), Vol. 50, p. 1211. Brief item on building up of worn edges and surfaces.

Report of Electric Welding Committee. S. S. Wales. Iron & Steel Engr. (October, 1929). Discussion. Vol. 6, pp. 561-562.

Safety and Control of Welded Joints in Steel Structures. R. Cajar. Stahlbau. (Supp. to Bautechnik) (Aug. 9, 1929), Vol. 2, pp. 185-188.

Specifications for Welding Steel Buildings by Electricity. F. P. McKibben. Canad. Machy. (Toronto) (Oct. 31, 1929), Vol. 40, pp. 56, 58 and 60.

Tests of Electrically Welded Trusses. R. R. Blackwood. Commonwealth Engr. (Melbourne) (November, 1929), Vol. 17, pp. 137-138. Report on tests to destruction of two electrically welded trusses, 7 to 8 ft. long, 1.5 to 3 ft. deep, made at Engineering School of Melbourne University; tests serve to demonstrate stiffness of welded joints.

Tests with Welded Lattice Girders. W. Gehler. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1747-1755. Notes on application of electric welding in bridge construction; results of tests carried out in government testing laboratory at Dresden on welded lattice girders stressed to destruction; results show that, whereas further research is necessary, electric welding in certain cases may be safely and successfully employed.

The Calorimetric Study of the Arc. P. P. Alexander. Journal of the A.I.E.E. (February, 1930), Vol. 49, No. 2, pp. 138-141.

The Fusion News (February, 1930), Vol. 1, No. 8. A Study of Penetration, from the Standpoint of Applying the Fundamental Theory to Metallic Arc Welding, by J. B. Green. Rail Joint Welding, by E. J. Shuler. Fundamentals of Overhead Welding.

The Repair of Steel Bridges by Electric Arc Welding. C. M. Taylor. Engineering and Contracting (February, 1930), Vol. 69, No. 2, pp. 63-65. Some examples of the reinforcement of trusses and girders by means of the electric arc. Corroded members restored and capacities increased at moderate cost.

Tube-Turns in Welded Pipe Layouts. R. E. Fritsch. Acetylene Journal (February, 1930), Vol. 31, No. 8, pp. 340-342. New fittings for welded pipe installation makes a more efficient system possible with further economies.

Unfired Vessel Code, The. C. W. Obert. Welding Journal (London) (November, 1929), Vol. 26, p. 356. Serial.

Welded Construction in Airplane Manufacture. A. Koppenhofer. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1727-1730. Combined construction method in airplane manufacture and use of welded structural parts with this method are explained; main advantages and disadvantages of system are discussed.

Welded Grabs. L. Schulze. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1755-1758. Details of grabs of extremely light weight for 12.5 ton capacity made of Union structural steel by electric welding process; results of preliminary tests.

Welded Line Joints for Steel Pipe. W. I. Gaston. The Iron Age (Feb. 6,

1930), Vol. 125, No. 6, pp. 435-437. Types of welded joints used today, considered from the standpoints of strength, flow conditions and economy.

Welded Steam Piping. W. Tallmadge. Universal Engr. (January, 1930), Vol. 51, pp. 26-29.

Welding an Aluminum Casting. C. H. S. Tupholme. Foundry Trade Journal (London) (Dec. 19, 1929), Vol. 41, p. 441.

Welding Artistic Iron Decorations. Welding (February, 1930), Vol. 1, No. 3, pp. 253-254. The creation of artistic metal work would be almost impossible without the use of welding and modern brazing methods.

Welding Dock and Harbor Structures. Dock and Harbour Authority (London) (December, 1929), Vol. 10, p. 60. Details of methods of reinforcement of steel girders by welding arc.

Welding Facts and Figures. T. Richardson. Welding Journal (London) (October and November, 1929). Serial. Vol. 26, pp. 312-314, 358-362.

Welding for Boilers, Pressure Vessels and Steam Lines. C. W. Obert. Power Plant Eng. (Feb. 1, 1930), Vol. 34, pp. 174-175.

Welding in Chemical Engineering. J. R. Booer. Chem. and Industry (London) (Jan. 10, 1930), Vol. 49, pp. 17T-20T. Attention is called to more important of high-temperature phenomena and their effects in application of fusion welding to chemical engineering; of sources of heat most important are oxy-acetylene flame and electric arc; summary of behavior of aluminum, chromium and chromium steels, steels, lead, monel metal, nickel and zinc.

Welding in Machinery Manufacture. H. Neese. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1738-1739. Advantages of welding in machinery manufacture are briefly set forth; good machines, good electrodes, and good training of welders are, however, absolutely necessary.

Welding in Railroad Practice. Bardtke. V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1733-1737. Extensive use of welding in railroad construction and maintenance is set forth, and examples are given showing methods heretofore employed and possibilities which welding technique offers.

Welding Iron and Steel by Electric Arc. O. A. Tilton. Welding (February, 1930), Vol. 1, No. 4, pp. 229-231. Its fundamental principles and the various applications are clearly stated for the benefit of the prospective users of this process.

Welding Jig Facilitates Foundry Assembly. Iron Trade Review (Feb. 20, 1930), Vol. 86, No. 8, p. 49.

Welding of Cast Iron and Cast Steel. W. Hoffmann. Autogene Metallbearbeitung (Halle) (Nov. 15, 1929), Vol. 22, pp. 331-333. Experiments are carried out in order to determine behavior of various iron and steel castings when welded; average values of quantity which can be obtained are tabulated.

Welding of Structural Steel. H. Neese. (Schweissen im Stahlbau.) Stahlbau. (Supp. to Bautechnik.) (July 12, 1929), Vol. 2, pp. 161-167. Results of tests of welded structural steel members; analysis of stresses in welds.

Welding on the New Ford Motor Car. Welding Journal (London) (October, 1929), Vol. 26, pp. 326 and 328.

Welding Procedure Control. O. Trentham. Soc. Automotive Engineers' Journal (December, 1929), Vol. 25, pp. 677-678. Discussion of materials and procedure for production welding which should be determined by management; six factors of procedure control, including check of welders, selection and inspection of material, design and layout of welded joint, preparation for welding, organization and welding technique, and inspection and test; strength and elongation of welded joints; welded joints in steel; welding rods for welding steel.

Welding Saves the Day. Indus. Eng. (December, 1929), Vol. 87, pp. 618-621. Brief illustrated description of specific application of welding to plant repair.

Welding Technology. Fuechsel. (Schweisstechnik). V.D.I. Zeit. (Berlin) (Dec. 7, 1929), Vol. 73, pp. 1725-1726. Brief notes on applications and limitations of welding, introductory to series of articles in same Journal on welding practice, each of which is indexed separately.

Welding Used in Shop Fabrication and Field Erection of Large Gantry Cranes. The Iron Age (Feb. 13, 1930), Vol. 125, No. 7, p. 509.